AIRCRAFT ENGINES

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AIRCRAFT ENGINES

PREFACE

This book was written for the enlisted men of Naval Aviation. It is one of a series of books designed to give them the necessary information to perform their aviation duties.

A knowledge of aircraft engines is of primary importance to Aviation Machinist Mates responsible for general maintenance work. But the subdivisions of Aviation Machinist Mates—that is, Aviation Hydraulics Mechanics, Aviation Instrument Mechanics, Aviation Carburetor Mechanics, Aviation Propeller Mechanics, and Aviation Flight Engineers—all of them need an understanding of why and how aircraft engines operate before pursuing their specialties. All of them need to know the relationship of their specialties to the broad subject of engines. Also they must be prepared to perform general maintenance work when the occasion demands it. Specialists should not be narrowly limited to their specialties alone.

Starting with the basic principles of engine operation, this book discusses the five main systems which apply to all aircraft engines. Information on the mechanical system, the fuel system, the ignition system, the lubrication system, and the cooling system concludes with a general discussion on engine accessories, problems of overhaul, storage, and trouble shooting. Then, getting specific, there are descriptions and service hints about six of the outstanding aircraft engines used in Naval Aviation.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Naval Air Technical Training Command and the Training Courses Section of the Bureau of Naval Personnel.

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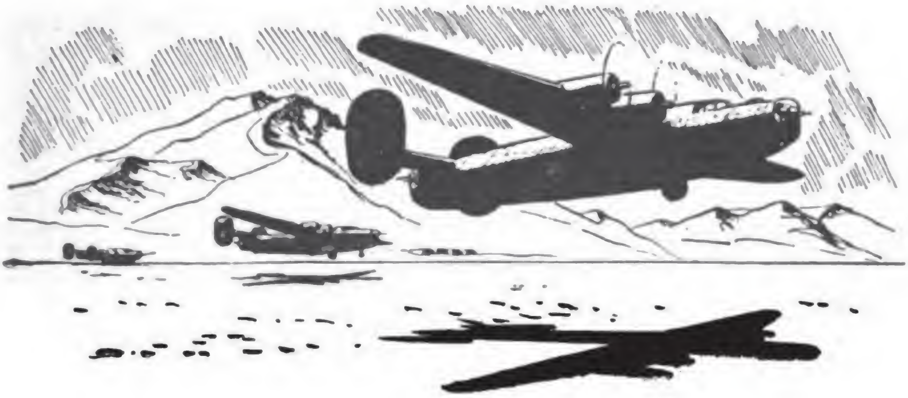


CHAPTER 1

ENGINE PRINCIPLES

WORK AND POWER

There is a trim Hellcat fighter ready for action out there on the line. Well, nearly ready. That 2,000 horsepower engine needs a preflight inspection before take off. Do you want to roll up your sleeves and go to work? O. K.! But wait a minute. How much do you know about that powerful engine? Before you begin the job you had better be sure you understand what you are doing. There are a few fundamental principles that you should know about engines.

The words WORK and POWER are not new to you. But it may be a new idea to think of work as the product of a force multiplied by the distance through which the force acts. For instance, if you lift a 100-pound weight to a height of 3 feet, you have really applied a force of 100 pounds through a distance of 3 feet and have done 300 foot-pounds of WORK. Thus you will find a unit of work referred to as the FOOT-POUND, usually written as ft.-lb. for short.

You can lift that 100-pound weight in one movement, and it probably would not take you more

than a second. But your favorite brunette—who tips the scales at 109 pounds—would really have a struggle lifting that weight. On the other hand, you could arrange a rope and a system of pulleys, called a block and tackle, so that she could easily lift your 100-pound weight 3 feet by pulling on one end of the rope. Sure, she would do the same amount of work, but it would take her longer—perhaps 4 seconds.

In lifting the weight unaided, you exert more POWER than your girl. But this indicates that power involves a TIME ELEMENT. Right! Power is always expressed in WORK PER UNIT OF TIME. In the case mentioned, you required only one-fourth as much time as your 109-pound brunette. This means she exerted only one-fourth as much power as you did. You exerted 300 ft.-lb. per second. She exerted 300 ft.-lb. in 4 seconds, or 75 ft.-lb. per second. This relation is pictured for you in figure 1.

The common unit of power is the HORSEPOWER, abbreviated hp. No; it does not have anything to do with a horse, although probably the expression originally meant the amount of work a horse could do in a specified time. But when you speak of the horsepower of an engine, you are referring to the power required to lift a weight of 33,000 pounds through a height of 1 foot in 1 minute—33,000 FT.-LBS. PER MIN. If you want to reduce this to seconds, simply divide by 60 and you get 550 FT.-LBS. PER SEC.

Remember, work is the product of a force and a distance, and power is work per unit of time. Consequently, if you lifted 1 pound through a height of 33,000 feet in 1 minute, the work done would still be 33,000 ft.-lbs. and the power exerted would still be 33,000 ft-lbs. per min., or 1 hp.

Now don't form the mistaken idea that work is done only when a force is applied for lifting. The force may be exerted in any direction. Suppose you DRAG that 100-pound weight along the ground. You are still exerting a force—a much smaller force—and its line of action is approximately horizontal. The amount of force would depend on the smoothness of the ground. If you

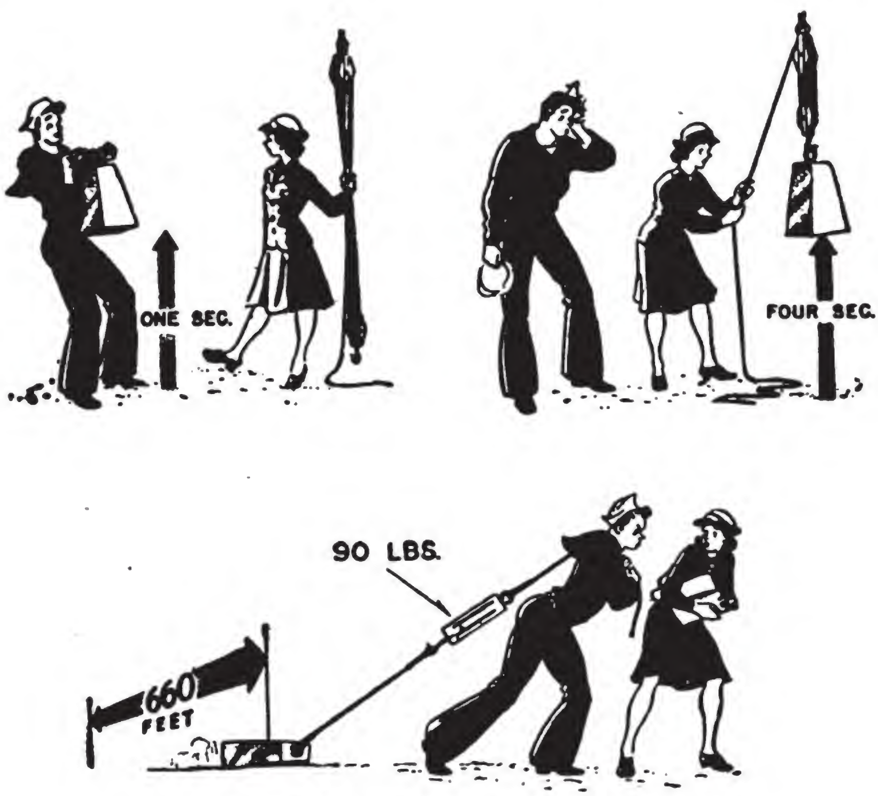


Figure 1.—Man Against Machine.

were to hook a spring scale to that weight and were to drag it by pulling on the handle of the scale, you would notice that the scale registered a certain number of pounds. The reading of the scale would be the force required to drag the weight. If you exert 40 pounds and drag the weight 660 feet in 2 minutes, you will have done 40×660—that is, 26,400 ft.-lbs. of work in 2 minutes, or 13,200 ft.-lbs. each minute. And since a

horsepower is 33,000 ft.-lbs. per minute, you will have expended $\frac{13,200}{33,000}=0.4$ hp.

How does all this apply to airplanes?

In its simplest form it comes back to the fact that the air is constantly tending to hold back an airplane when it is in flight. Of course, this resistance has to be overcome if an airplane is to fly. Suppose an airplane is moving at 220 feet per second (which is 150 miles per hour—mph.) and the total resistance caused by the air is 250 pounds. How much power is required to keep the airplane moving at this speed? Well, the work per second is $250 \times 220 = 55,000$ ft.-lbs. But 1 horsepower is 550 ft.-lbs. per second, so you divide 55,000 by 550 and get an answer of 100 horsepower.

ENERGY INTO WORK

Now you want to know how you are going to get enough of this power to spin the propeller of a Hellcat. You do it by harnessing the energy created by combustion. COMBUSTION is simply burning, although technically it means the uniting of fuel and oxygen. This process is accompanied by the generation of heat. And heat contains energy which may be converted into work.

Gasoline, as you would guess, has greater heat energy per pound than any other common substance. That's the reason it makes an ideal fuel for airplane engines. The oxygen is supplied by the air, so you can see that combustion requires both fuel and air. An airplane engine uses about 15 pounds of air to each pound of fuel.

There are two simple laws of physics that you ought to grasp fully and then you'll be ready to tackle that aircraft engine.

First, if the temperature of a confined gas is not changed, the pressure will increase as the volume is decreased—and conversely, the pressure will decrease as the volume is increased. That's Boyle's law, but you don't need to worry about the name. A simple demonstration of how this law works may be made with a toy balloon. If you squeeze the balloon, you reduce the volume, and the air inside exerts a greater pressure. If you squeeze hard enough, the pressure will burst the balloon.

Second, if a gas under a constant pressure is so confined that it is free to expand, an increase in the temperature will cause a proportionate increase in volume. This is Charles' law. If you hold your inflated balloon over a stove, the increase in temperature will cause the air inside to expand, and if the heat is great enough your balloon may burst. Heat of combustion is the reason for the expansion of the gas in the cylinder of an engine.

There you have the basic principles on which the aircraft engine operates. Actually an engine is a DEVICE FOR CONVERTING HEAT ENERGY INTO MECHANICAL WORK. In a nutshell, here's the way the gasoline internal combustion engine operates—gasoline is mixed with air, and the mixture is forced into a CYLINDER. The conversion of the energy of the fuel into work is accomplished within the cylinder as shown in figure 2. The rate at which the work is done determines the power.

The mixture is compressed by a PISTON and then ignited by an electric spark. When this compressed mixture is ignited, the resulting gases of combustion expand very rapidly and force the piston to move away from the end of the cylinder. This downward motion of the piston

is transferred to a CONNECTING ROD which in turn transmits a circular, or rotary, motion to a CRANKSHAFT. And the rotating crankshaft rotates the propeller. Also, the rotating crankshaft forces the piston back up toward the end of the cylinder.

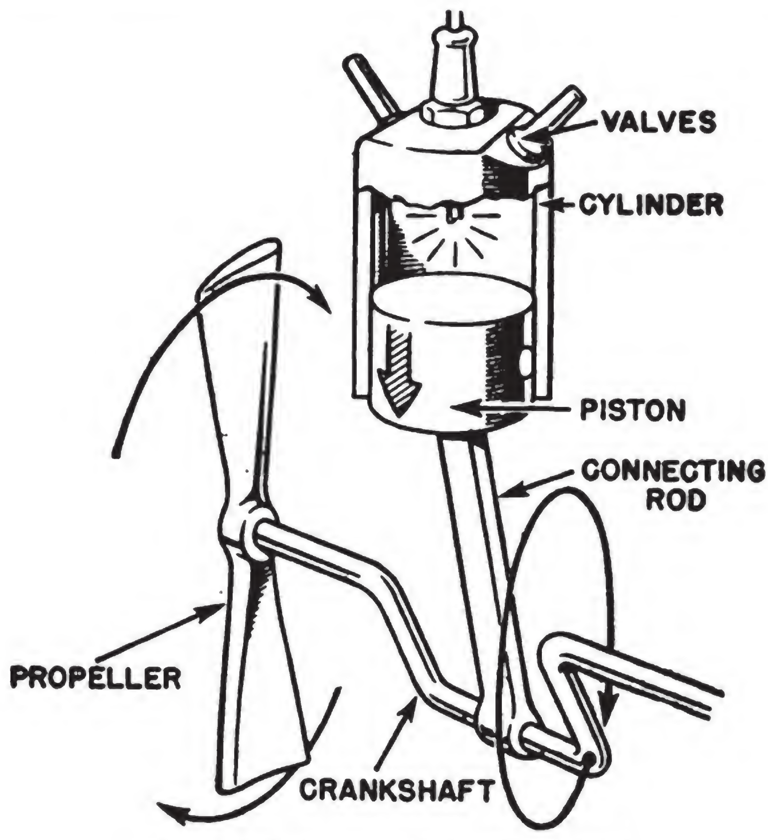


Figure 2.—Diagram of engine operation.

A VALVE in the top, or head, of the cylinder opens to let out the burned gases. Then it closes and another valve opens to let in the fresh mixture of fuel and oxygen. The expulsion valve is called the EXHAUST valve. And the valve letting in the new mixture is called the INLET, or INTAKE, valve. These valves are operated by a system of GEARS and CAMS so that they open and close at the right time.

FOUR-STROKE CYCLE

Each complete movement of the piston in one direction is called a STROKE. The series of events which takes place between the entrance of a charge of fresh fuel mixture and the exhaustion of the burned gases is called a CYCLE. The main aircraft engines use a FOUR-STROKE CYCLE—there are four strokes of the piston in each cycle. In figure 3, you see the basic operations involved in a typical aircraft engine.

The engine is now in operation so let's look at view (*A*). The piston is moving downward, or toward the crankshaft as a charge of combustible mixture is forced into the cylinder through the open intake valve. This stroke is the INTAKE or ADMISSION STROKE.

In view (*B*) the piston has passed its lowest point and is moving upward, or away from the crankshaft. The charge is being compressed. This is the COMPRESSION STROKE. During this stroke both intake and exhaust valves are closed. The ratio of the volume of the cylinder when the piston is at the bottom center to the volume of the cylinder when the piston is at the top center is called the compression ratio. Shortly before the piston reaches the top of the compression stroke, a spark is produced across the points of the spark plug, and the compressed mixture is ignited. By having the ignition occur just before the piston reaches top center, complete combustion will occur just as the piston reaches top center, and the pressure is utilized most efficiently.

The hot gases obtained by combustion create tremendous pressure on the piston and force it to move downward again as in view (*C*). This is the POWER or expansion STROKE. Near the end of the power stroke, the pressure is much reduced

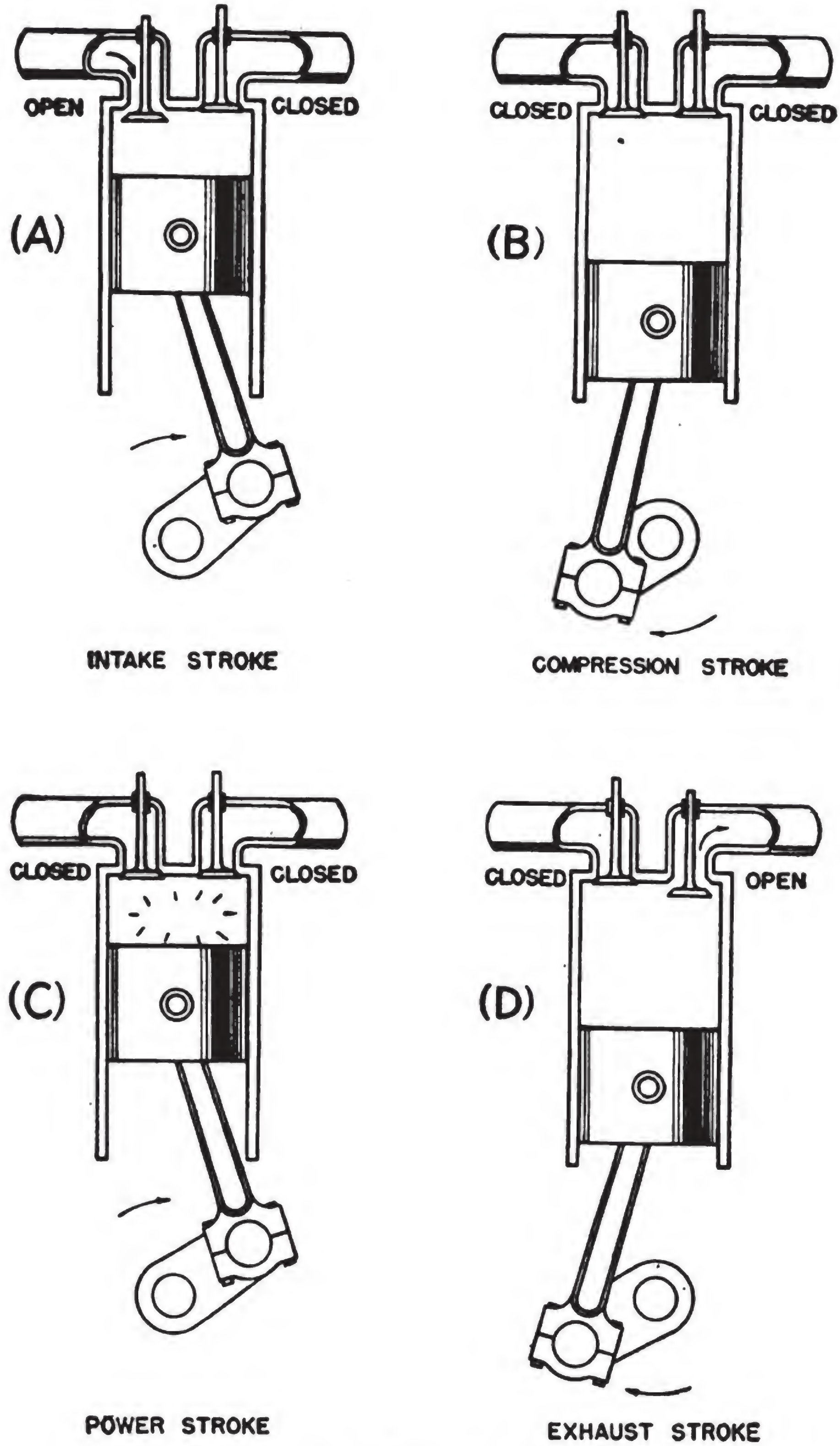


Figure 3.—Four-stroke cycle.

because of the expansion of the gases. At this stage the exhaust valve opens, and the gases start to flow out of the cylinder.

The moving connecting rod causes the piston to return upward once more, as in view (*D*). This is the EXHAUST OR SCAVENGING STROKE. The remaining burned gases are forced out of the cylinder.

The cycle is now complete and the piston is again ready to start on another intake stroke.

Note that for each complete cycle of operation, the piston makes two trips up and two trips down. For every up and down motion, the crankshaft makes one revolution. Therefore the crankshaft makes two complete revolutions for each four-stroke cycle. Since all the pistons in an engine are connected to the same crankshaft, this condition is true, regardless of the number of cylinders. This means also that each cylinder in an engine fires once for every two revolutions of the crankshaft.

The power strokes in the various cylinders are timed to give consecutive "pushes" at equal intervals so as to keep the crankshaft turning smoothly.

The four-stroke cycle is advantageous for aircraft engines because of its flexibility (ability to accelerate quickly) and its dependability. The separate intake stroke makes it possible to do a complete job of getting a fresh charge into the cylinder. The separate compression stroke gives excellent engine efficiency (a highly compressed mixture produces greater power). The separate power stroke lets the expanding gas act on the piston during practically all of its downward travel. And finally, the separate exhaust stroke does a clean job of removing burned exhaust gases.

TWO-STROKE CYCLE

Despite these advantages, the auxiliary power plants for the big flying boats make good use of a

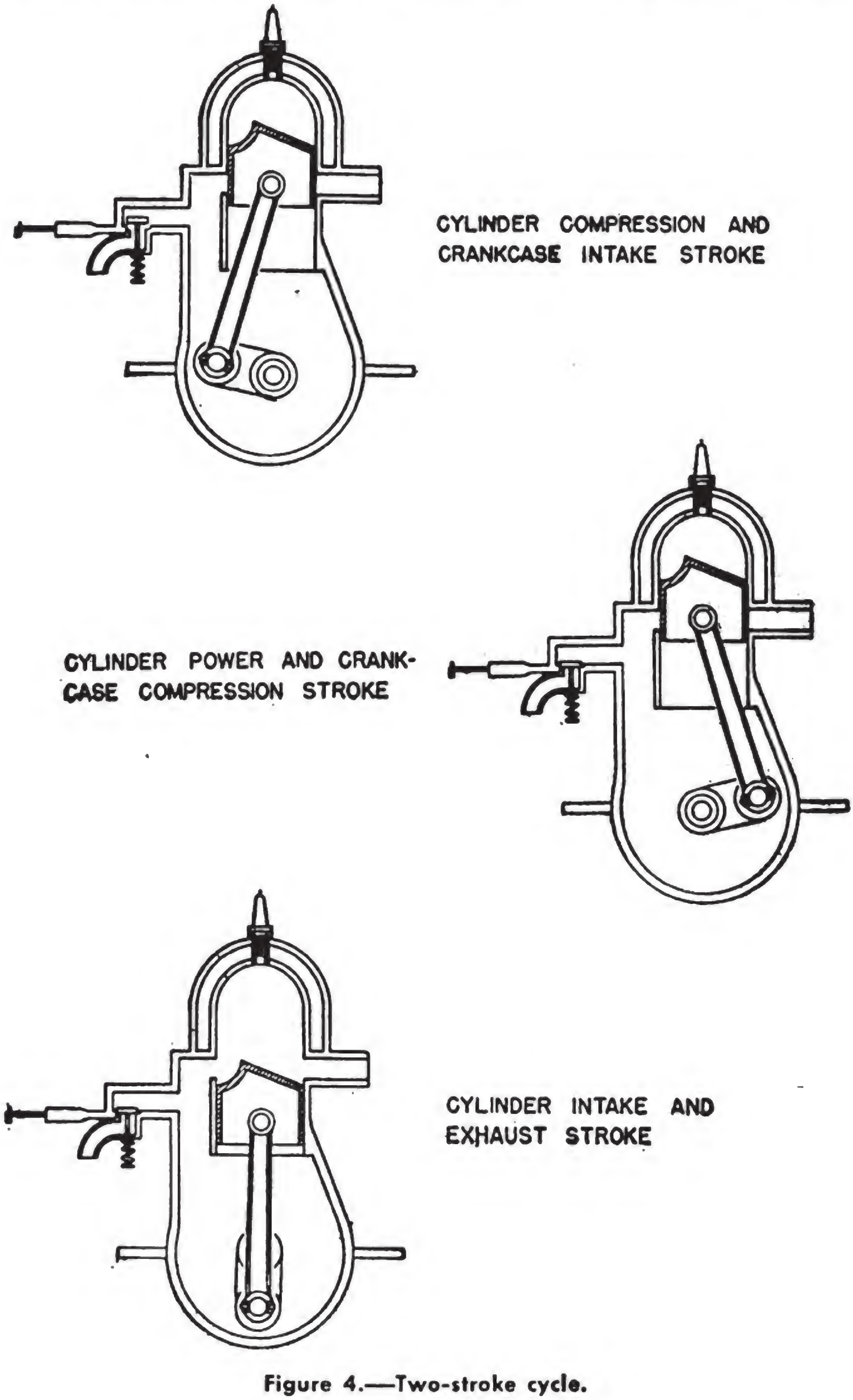


Figure 4.—Two-stroke cycle.

less efficient two-stroke cycle. But in those engines, economy is secondary to high power output.

In figure 4, you see the basic operations involved in the two-stroke cycle. The valves are arranged differently, and only one upward and one downward stroke are necessary to make a complete cycle. The intake and compression strokes are combined in the upward movement of the piston. The power and exhaust strokes are combined in the downward movement of the piston. The crankshaft makes one revolution for the complete cycle. All cylinders fire once for every revolution of the crankshaft.

Because of its more frequent power impulses, an engine using a two-stroke cycle may be operated at extremely high speeds. But it is wasteful of fuel. A part of each fresh mixture is discharged with the exhaust gases. All of the burned gases are not exhausted, and a small portion is compressed with each new mixture. Also, considerable difficulty is encountered in attempting to cool a cylinder that fires every revolution.

IN-LINES AND RADIALS

Forty years of aviation progress have wrought great differences in aircraft engines, even though the principle of operation has remained the same. Beyond the mere fact that the same principle is used, there is little resemblance between the first aircraft engine and the power plant of the modern airplane. The simple installation in the Wright brothers airplane has given way to engines whose horsepower is measured in four figures.

Early aircraft engines were primarily water-cooled engines. Before and during the last war, however, there was a swing toward air-cooled engines in France, but most American manufac-

turers continued to cling to the water-cooled type. The famous Liberty engine, developed during this period, was considered a great accomplishment because it weighed only 2.02 pounds per developed horsepower.

About 1920 the Navy began to buy air-cooled engines. Since then water-cooled engines have been replaced steadily. Today, you will find that there are practically no water-cooled engines in Naval aviation. Those still in use are either experimental or obsolete.

There are two general classes of aircraft engines now in use—IN-LINE and RADIAL. The reason for these names is logical enough. In-line engines have the cylinders arranged on the crankcase IN A STRAIGHT LINE. Radial engines have the cylinders arranged radially on the crankcase like THE SPOKES OF A WHEEL. Figure 5 shows various cylinder arrangements.

The types of in-line engines are known as V, W, X, vertical, and opposed. The letters symbolize the arrangement of the cylinders. Sometimes vertical- and V-type engines are installed with the crankshaft over the cylinders. It is then called an inverted type. The vertical type engine is a somewhat heavier engine per horsepower than any of the others, but it has the advantage of presenting a minimum resistance to the air stream.

V-type engines are the most common of the in-line engines. The cylinders are arranged in two rows, or banks, which form a V. These engines generally contain either 8 or 12 cylinders with angles of 90°, 60°, or 45° between banks. A light, strong, and powerful V-type engine may be built by arranging the cylinders of the two banks directly opposite each other or slightly staggered. In this way two connecting rods may be used on each crank pin of the crankshaft.

In-line engines were developed generally as liquid-cooled engines. But air-cooled, in-line engines, such as the Ranger V-770-6, with cylinders

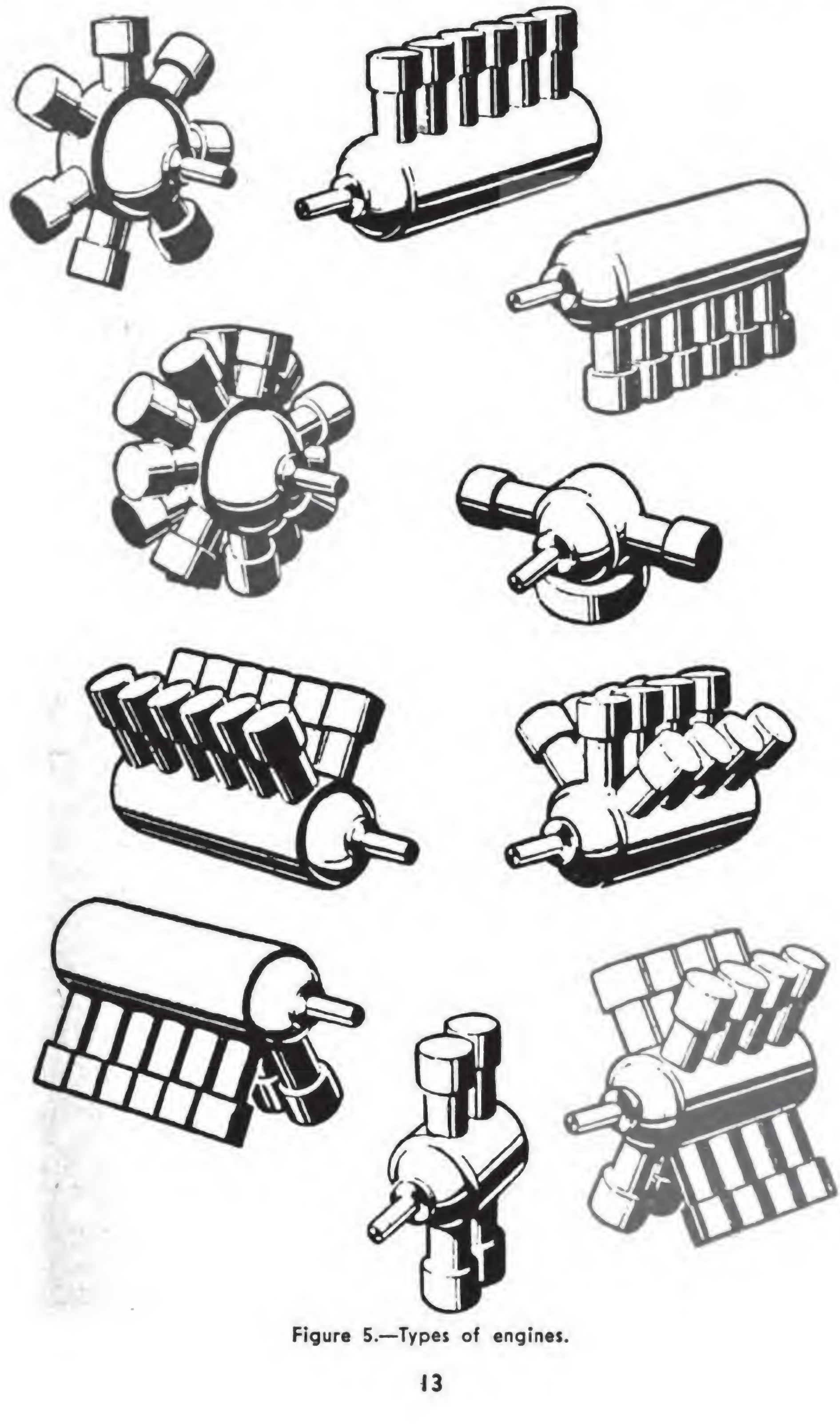


Figure 5.—Types of engines.

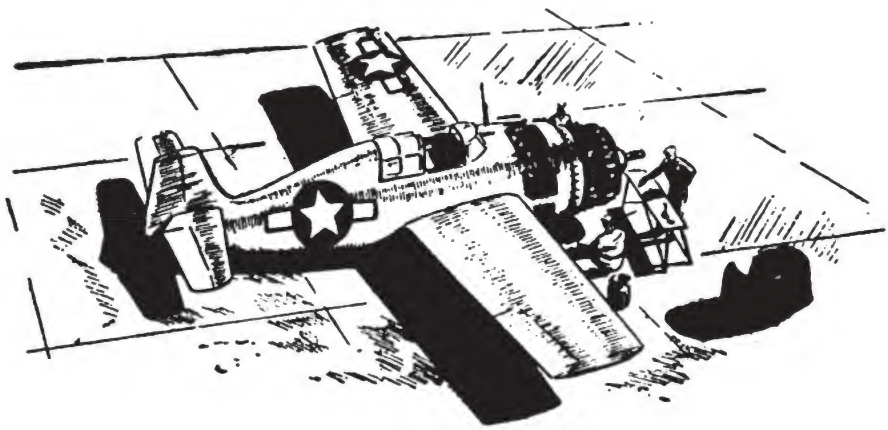
arranged in rows running from fore to aft, are now in use. The air-cooled in-line engine presents LESS RESISTANCE TO THE AIR STREAM than does the air-cooled radial engine.

Radial engines are built with the cylinders evenly distributed around the crankcase in one, two, or more banks. Generally, these engines have from seven to nine cylinders in a circular row, or as many as 18 in two rows of nine each. Today, most air-cooled engines are of the radial type, and they have a distinct advantage over other types of engines because of their LOW WEIGHT PER HORSEPOWER.

Whenever two circular rows of cylinders are employed, a two-throw 180° type of crankshaft is used. The cylinders are stationary and can be streamlined by use of baffles and cowling. But, even so, they offer considerable resistance to the forward motion of the airplanes as compared with an in-line engine.

ENGINE SYSTEMS

In all aircraft engines, there is a MECHANICAL SYSTEM consisting of all the moving and the stationary parts. Then there is the FUEL SYSTEM which feeds the mixture of gasoline and air into the cylinders. The IGNITION SYSTEM controls the electrical spark which ignites the mixture of gasoline and air in the cylinder. Every engine also has a LUBRICATION SYSTEM which oils the moving parts and keeps them running smoothly without undue friction or wear. The COOLING SYSTEM maintains the temperature of an engine within safe limit. All five of these systems are necessary in order to harness the power created by combustion in the cylinder. In the next few chapters you'll find out just how they all work together.



CHAPTER 2

MECHANICAL SYSTEM

CYLINDERS

You've just learned that the mechanical system of an engine includes all of the moving and stationary parts. In other words, "It's the works." Moving parts include the pistons, connecting rods, crankshaft, valves, valve operating mechanisms, reduction gears, accessory drives, and superchargers. The stationary parts include the cylinders, crankcase, and subassemblies used with each.

To know your engines, you've got to understand the individual parts and how they work together. So let's get down to brass tacks—or to aluminum cylinders in this case.

The cylinders of an aircraft engine are of steel and aluminum construction (fig. 6). They are divided into two main sections, the barrel and the head. The barrels are machined from steel forgings (formed by heating and hammering), or centrifugal castings (formed in molds), and some have forged aluminum cooling muffs. Deep-cut cooling fins have been machined in these muffs and

are shrunk over the central portion of the barrel. The heads are aluminum alloy castings or forgings with closely spaced cooling fins and integral rocker housings. Forged heads, which have been developed only recently, are able to withstand greater pressures and have greater heat conductivity because of their increased density. The aluminum heads are screwed and shrunk onto the cylinder barrels, forming permanent joints.

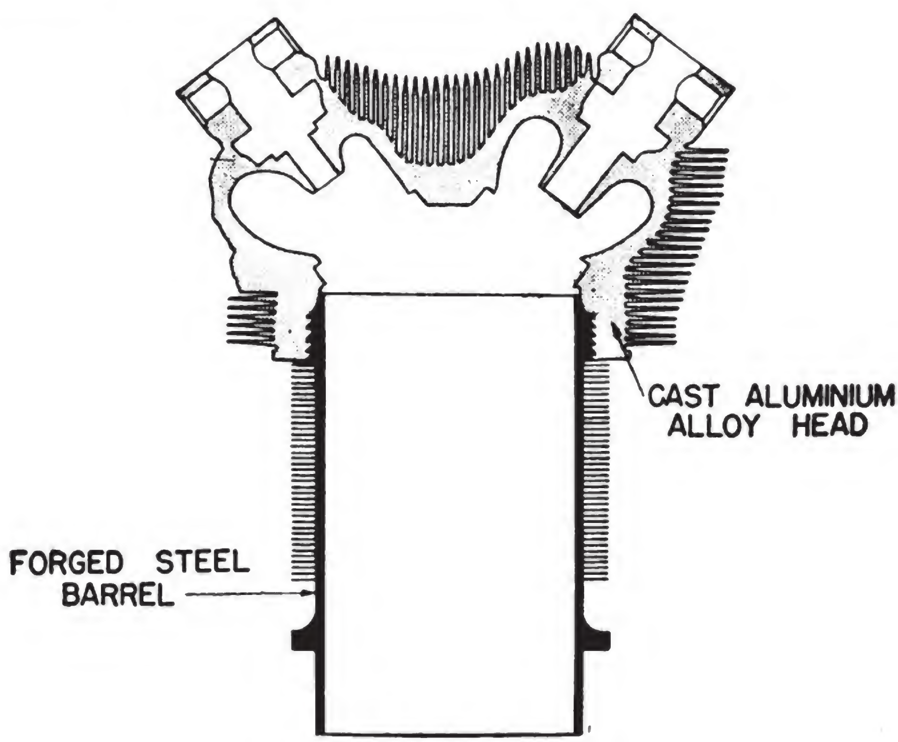


Figure 6.—Cutaway cylinder.

On most engines you'll find that each cylinder has one inlet valve and one exhaust valve. The cylinders are provided with mounting flanges and are secured by studs and nuts or cap screws to the crankcase.

VALVES

Cylinder valves, as you have learned, open and close the passageways which admit fresh gases into the cylinders and release burned gases. The

valves, shown in figure 7 are the conventional types used in American aircraft engine cylinders. Generally, valves are constructed of tungsten or silchrome steel. Both maintain their strength at high temperatures.

The head of a valve is the part which opens and closes the passageways. It has a ground face which rests on the valve seat in the cylinder when in a closed position. A thin layer of stellite or

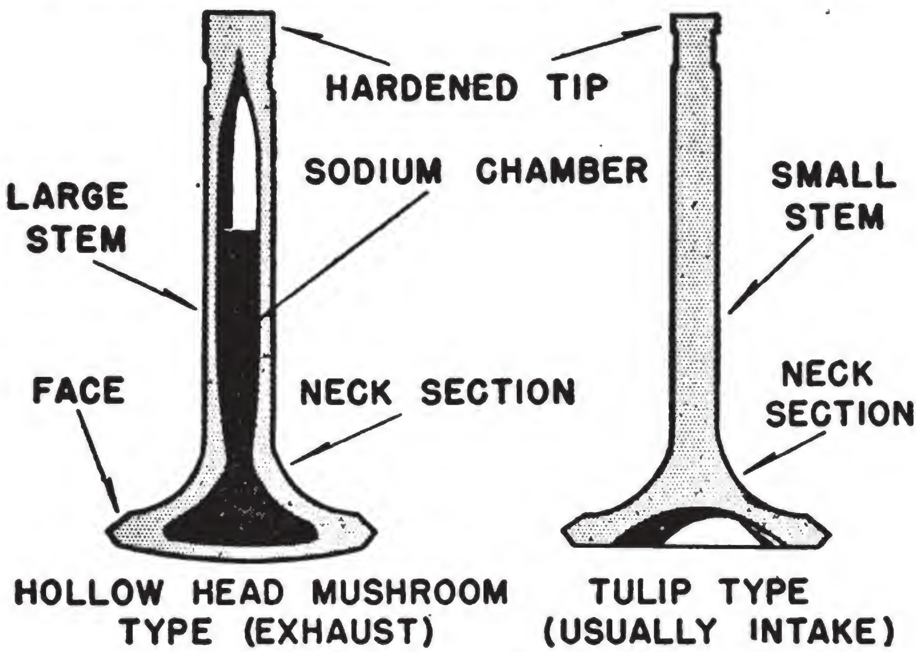


Figure 7.—Valves.

other heat-resisting material fused to a stainless steel valve face, greatly retards corrosion, pitting, and warping. This heat-resisting layer is particularly desirable for exhaust valves in high-performance engines.

The stem of a valve acts as a pilot for the valve head when it is operating. The guide for the valve stem is located in the cylinder head. Some exhaust-valve stems are hollow and are filled with a salt solution, mercury, or metallic sodium to reduce the operating temperature of the valve head. The heat of the valve is led away from the valve head

and out along the stem, from which it is eventually dissipated.

Exhaust valves, particularly in air-cooled engines, are constructed with heavier heads and larger diameter stems than are intake valves. Exhaust valves are thus able to withstand the high temperatures at which they operate. Added to the heat is the fact that each valve opens and shuts a thousand times every minute. (This is true if the engine is running at 2,000 revolutions per minute, you'll recall, since each valve opens and closes once for two revolutions of the crankshaft).

VALVE MECHANISM

The movement of the valves is controlled by cams. These are plates which move followers by means of projections or lobes on their outer surface. Take a look at figure 8, and you'll see how they work.

On single-row radial engines, the valve mechanism consists of a cam plate, on which the cam follower rollers run. The rollers are attached to the push rods. These rods operate rocker arms, mounted in rocker boxes on the cylinder head. And the rocker arms, in turn, open the valves. You can get an idea of the arrangement of the push rod and rocker arm assembly of a radial engine by examining figure 9.

The cams are geared to the crankshaft. These gears have to be timed to open and close the valves at the proper instant in relation to the position of the piston during a particular stroke. As the cam revolves, it alternately lifts the push rod and releases its pressure. As the pressure is released, a coil spring quickly forces the valve back on its seat, thus closing it.

The cam plate, in the nose section of figure 9, employs two tracks, each containing four lobes. One row operates the intake valves, and the other, the exhaust valves. In double row radial engines two cam plates are employed. One is in the nose section and operates the valves of the front row

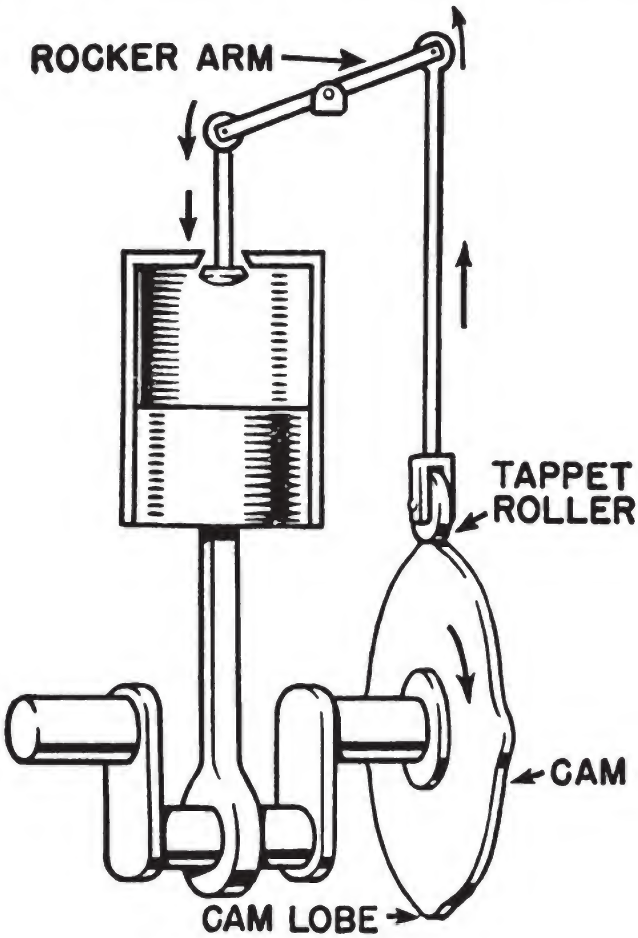


Figure 8.—Cam and follower.

of cylinders. The other is in the rear section and operates the valves for the rear row of cylinders.

In V-type aircraft engines the valve mechanism consists of one or two camshaft assemblies mounted over the valves on the head of each cylinder bank, as you see in figure 10. When two camshafts are used, one operates the intake valves and the other operates the exhaust valves.

Usually both camshafts are driven by one common gear. This, in turn, is driven by the crankshaft indirectly through a gear train. Where each cam operates two valves, a T-shaped tappet (small lever) is interposed between the cam and the two

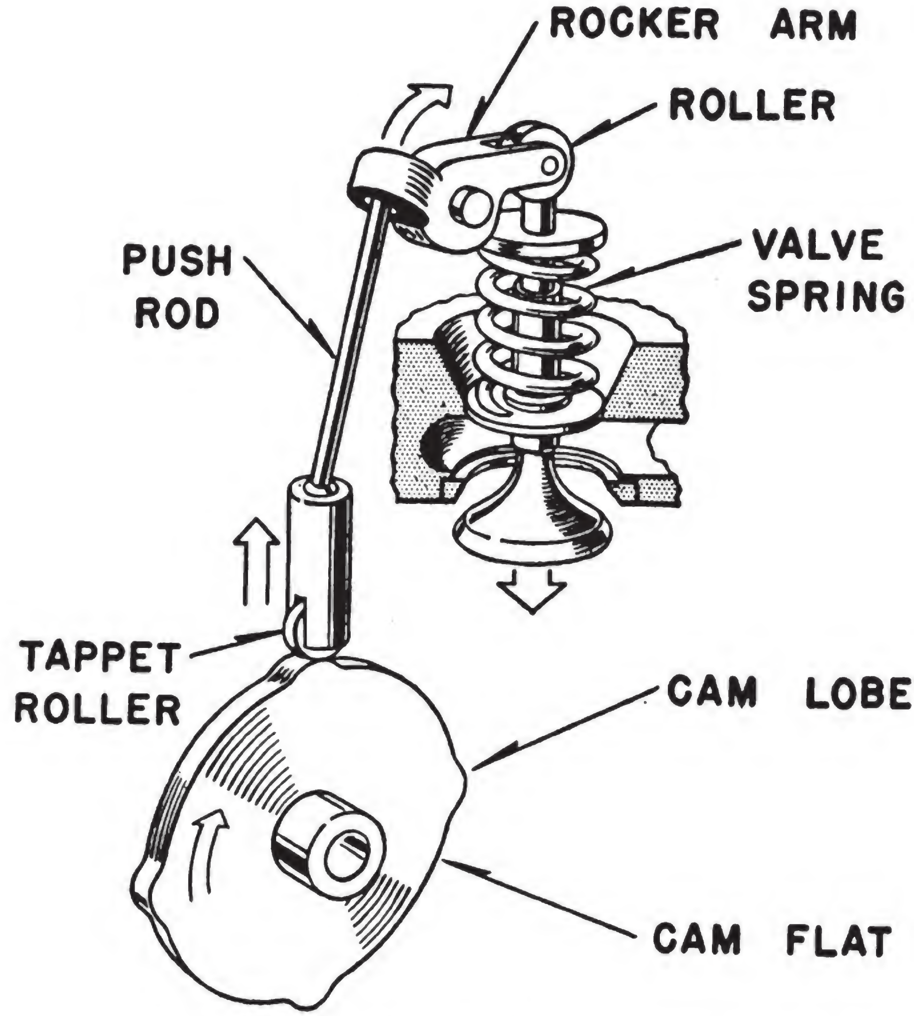


Figure 9.—Radial engine valve mechanism.

valve stems to provide a means for the cam to operate the two valves simultaneously.

When only one camshaft is used on each cylinder bank, it is driven directly by the crankshaft through a vertical driveshaft and conventional bevel gears. Each intake and exhaust cam oper-

ates two intake and two exhaust valves through a unique rocker arm arrangement.

Camshafts are generally machined from sil-chrome steel forgings. The cams are heat-treated in order to obtain a hard-wearing surface where they contact the valve tappets or rollers. Light alloy bearings attached to the cylinder head support the camshafts and are lubricated through the hollow camshaft journals.

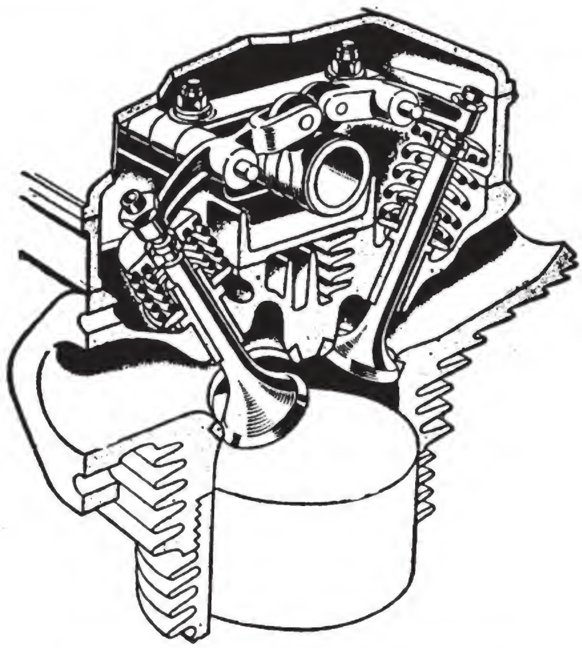


Figure 10.—In-line valve mechanism.

The valves are closed by coiled springs. In aircraft engines two or more concentric springs, one inside the other, may be used on each valve. The springs are compressed to position over the valve stems and securely held in place by a locking device. The use of multiple valve springs promotes operating safety, equalizes side pressure on the valve stem, and permits a higher spring tension within a restricted area. The most important advantage of multiple valve springs, however, is the elimination of valve-spring surging, or bouncing.

All valve mechanisms are TIMED so that the intake and exhaust valves will open and close at the proper moments. The specific VALVE TIMING for an engine is arranged at the time of assembly.

PISTONS

When the fuel mixture has been admitted to the cylinder, the piston serves as a plunger compressing the mixture, transmitting to the crankshaft the work accomplished by combustion, and forcing out the burned gases from the cylinder. The piston must have sufficient strength to withstand the combustion pressures, and yet it must be as light as possible to keep down inertia forces. When you realize that the piston must be accelerated to a velocity in excess of 2,000 feet per minute in some cases, and then brought to a stop and reversed TWICE EACH REVOLUTION, you can understand the importance of light yet sturdy construction.

Engine pistons are machined from a forged aluminum alloy which reduces operating stresses to a minimum and rapidly conducts heat away from the piston head to adjoining engine parts for radiation. This results in a comparatively low piston operating temperature and consequently a low heat transfer to the incoming charge during the intake stroke. You can see a diagram of a typical piston assembly in figure 11.

The piston head may be flat, convex or concave. It's easy to remember the difference between convex and concave by noting that a concave surface curves in like a "cave," while a convex surface curves outward. In some instances recesses are machined in flathead pistons for use in high compression engines to permit the valves to open without interference. As far as efficiency of

operation is concerned, it makes little difference which type is used. The inside of the head is usually ribbed for strength and to permit a high heat transfer to the oil splashed up from the crankcase.

There may be as many as six grooves in the piston to accommodate the compression rings and

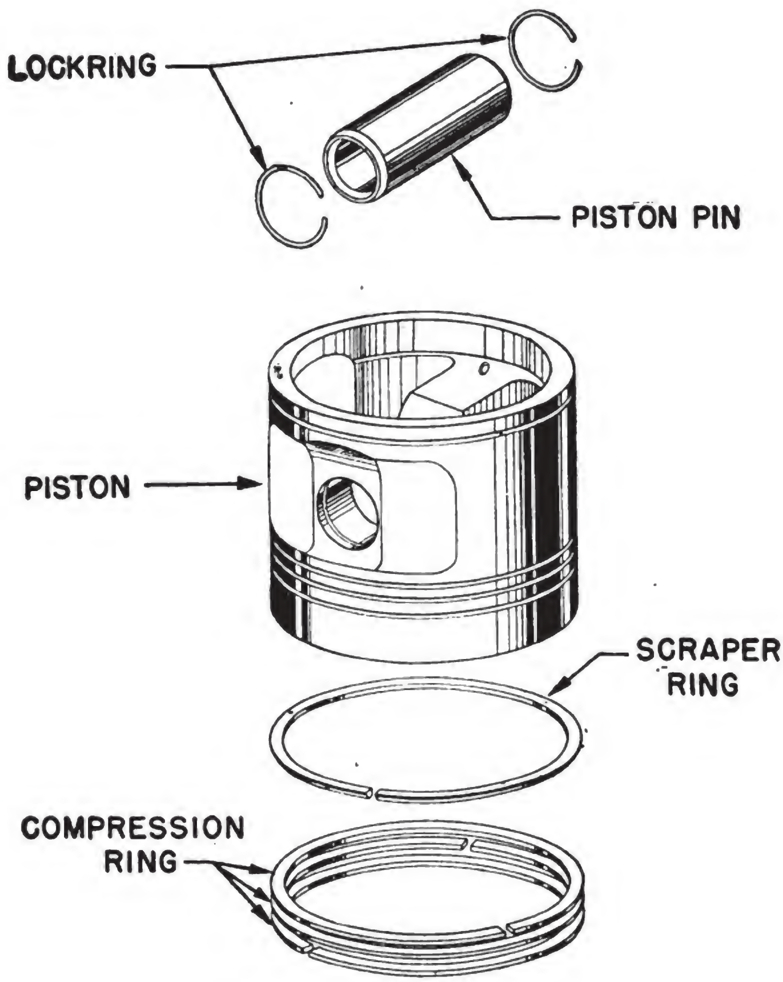


Figure 11.—Piston assembly.

oil-control rings. The latter are drilled through at several points to allow surplus oil scraped from the cylinder wall to be forced into the crankcase by the oil-control ring. A groove in the piston skirt, below the piston pin, accommodates an oil-

scraper ring which acts with the oil-control ring to prevent excessive oil consumption.

The sidewalls (the skirt of the piston) act as guides or bearing surfaces for the head and incorporate the piston-pin bosses. These are of heavy construction and are usually ribbed to carry the piston-pin load.

The PISTON RINGS PREVENT LEAKAGE of gas pressure from the combustion chamber and reduce to a minimum the seepage of oil into the combustion chamber. The rings fit into the grooves of the piston but spring out to make contact with the cylinder walls, and, when properly lubricated, form a gas seal. They must be capable of exerting sufficient spring pressure against the cylinder wall to perform their function, but with a minimum of friction. The majority of piston rings are made of high grade grey cast iron and are either rectangular or wedge-shaped sections. The gap in the piston ring, where it butts together in position in the cylinder, may be diagonal, step, or butt cut. Only a small portion of gas seepage occurs at the gap, regardless of the shape of the cut. The gaps are staggered (not in line) when the rings are installed.

The oil-control ring is usually similar in construction to a compression ring. Some manufacturers, however, use two thin rings as shown in (*C*) of figure 12. They are milled out at intervals on the lower side to permit the surplus oil from the cylinder wall to seep freely back into the crankcase through the drilled holes in the groove. An oil-scraper ring, beveled on its outside circumference, is shown in (*D*) of figure 12. Modern types of compression rings are similar to oil-scraper rings, but with only a slight bevel as pictured in (*B*) of figure 12.

The PISTON PIN, sometimes referred to as the wrist pin, CONNECTS THE PISTON ASSEMBLY TO THE CONNECTING ROD and is machined from a nickel steel alloy forging, hardened and ground. Take another look now at the pin pictured in figure 11. The pin is made hollow for lightness. The type used in aircraft pistons is free to move in bearings in the piston and in the small end of the connecting rod. It is known as the full floating type. A piston pin may be held in place by aluminum plugs or spring locks which prevent it from scoring the cylinder walls. Oscillating (swinging) and stationary types of piston pins are used principally in automotive engines.

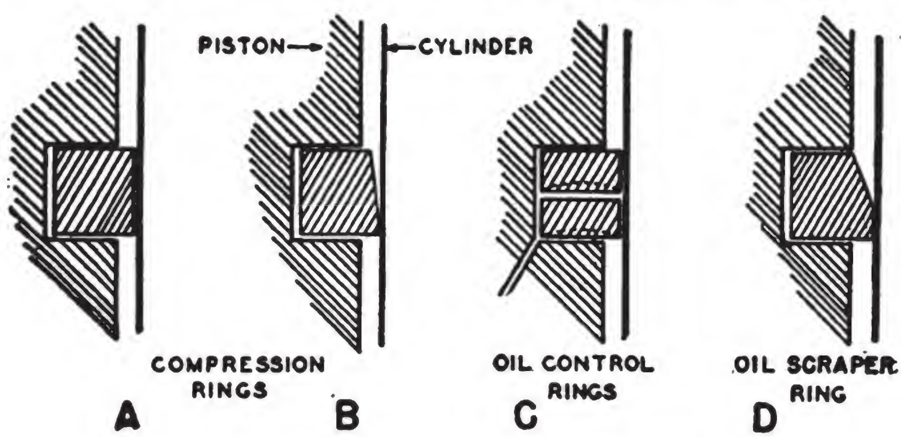


Figure 12.—Cross section of piston rings.

CONNECTING RODS

The CONNECTING ROD OR "CON" ROD IS THE LINK BETWEEN THE PISTON AND THE CRANKSHAFT. It transmits the power imparted to the piston by the expansion of the gasses of combustion. It transforms the up and down (reciprocating) motion of the piston into a rotary motion at the crankshaft.

In the radial aircraft engines used in the Navy, a heavy master rod is attached to the crank pin, with the articulated (or link) rods being attached

to the master rod (fig. 13). On single row engines the crankshaft is sometimes made in two pieces. When disassembled, this permits the master rod to slip in place over the crank pin so that the master rod used with this type of crankshaft does not require a split bearing. Articulated rods do not require split bearings, as the piston pin is inserted through the bearing at the other end and attached to the master rod.

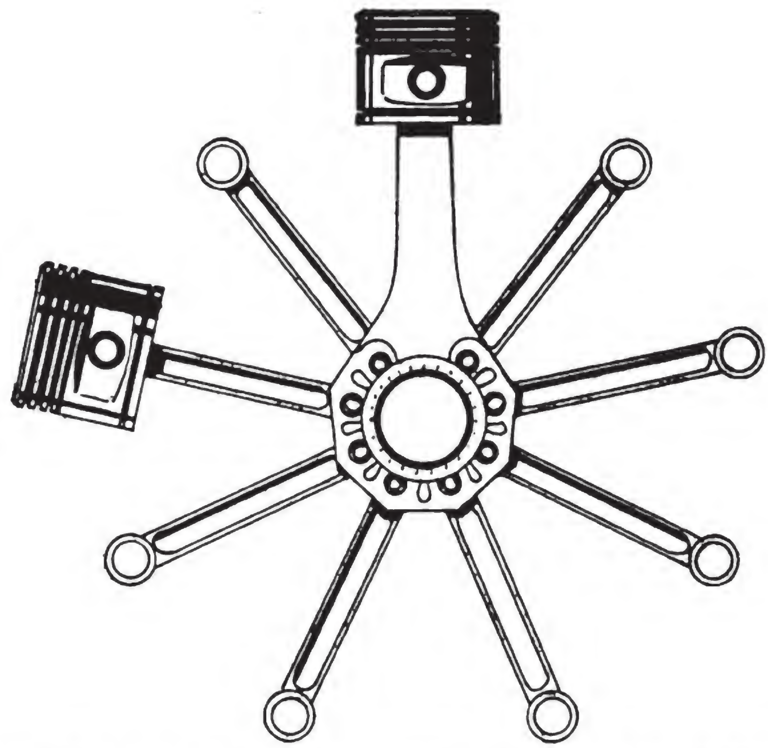


Figure 13.—Master connecting rod assembly. Knuckle pins of forged steel hold the connecting rods to the master rod.

In order to provide a softer metal for the piston pins and knuckle pins to bear against, bronze bushings are pressed into the connecting rods at those positions. All connecting rods are made of special alloy steel forgings, which are heat-treated for additional strength. They are finish-machined throughout.

The crankshaft of the engine receives the power developed on the piston and delivers it to the propeller. Note (*A*) in figure 14. In other words it converts the power stroke of the pistons into rotational force, which turns the propeller. The 360° type crankshaft (*B*) in figure 14, is conventional for all single-row radial aircraft

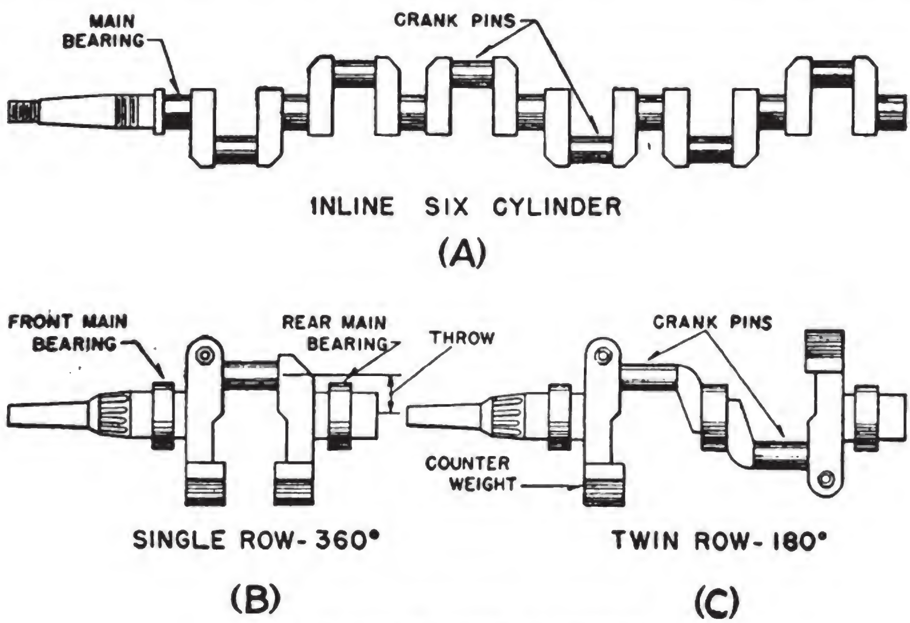


Figure 14.—Three types of crankshafts.

engines. This type of crankshaft employs two counterweights, one on each crankcheek, to counteract vibration created by the firing impulses. In high-powered engines, a dynamic damper or pendulum counterweight is often mounted on both front and rear cheeks, in place of the conventional and rigidly mounted counterweight. This weight is free to oscillate (swing) in a restricted arc and in the plane of rotation of the counterweight.

The 180° type of crankshaft, (*C*) in 14, may have two or four crank throws, with each pair of throws arranged around the crank journal 180°

apart. Crankshafts used in double-row radial engines employ two crank throws. The crank throws then balance each other. Therefore, only two counterweights or dynamic dampers are employed to counteract torsional vibration.

CRANKCASE

The crankcase, which you see in figure 15, transmits the thrust from the propeller to the fuselage of the airplane. It affords rigidity to the entire engine structure, and, as you have observed, serves as the base or bed member on which the rest of the engine is constructed. It supports the cylinders and crankshaft and serves as the means of attaching the engine to the fuselage. You'll discover, as you work on engines, that the crankcase, in general, ties various parts of the engine together and at the same time withstands stresses created by gas pressures and bending which may be caused by unbalanced forces. It also provides a tight enclosure to prevent the loss of lubricating oil and to protect the internal parts from dust and dirt.

The crankcase of a typical engine is composed of three forged steel or aluminum alloy sections—front, center, and rear, held together by through bolts. Around the outer circumference of the crankcase assembly, cylinder mounting pads are arranged. A chamber, called a sump, is provided on the lower side of the crankcase to collect the oil supply. The DIFFUSER CHAMBER, which distributes the mixture of air and fuel to the various cylinders, is usually in the crankcase section also. There are also accessory drives in the crankcase. These accessory drives lead to mountings where the necessary accessories may be attached.

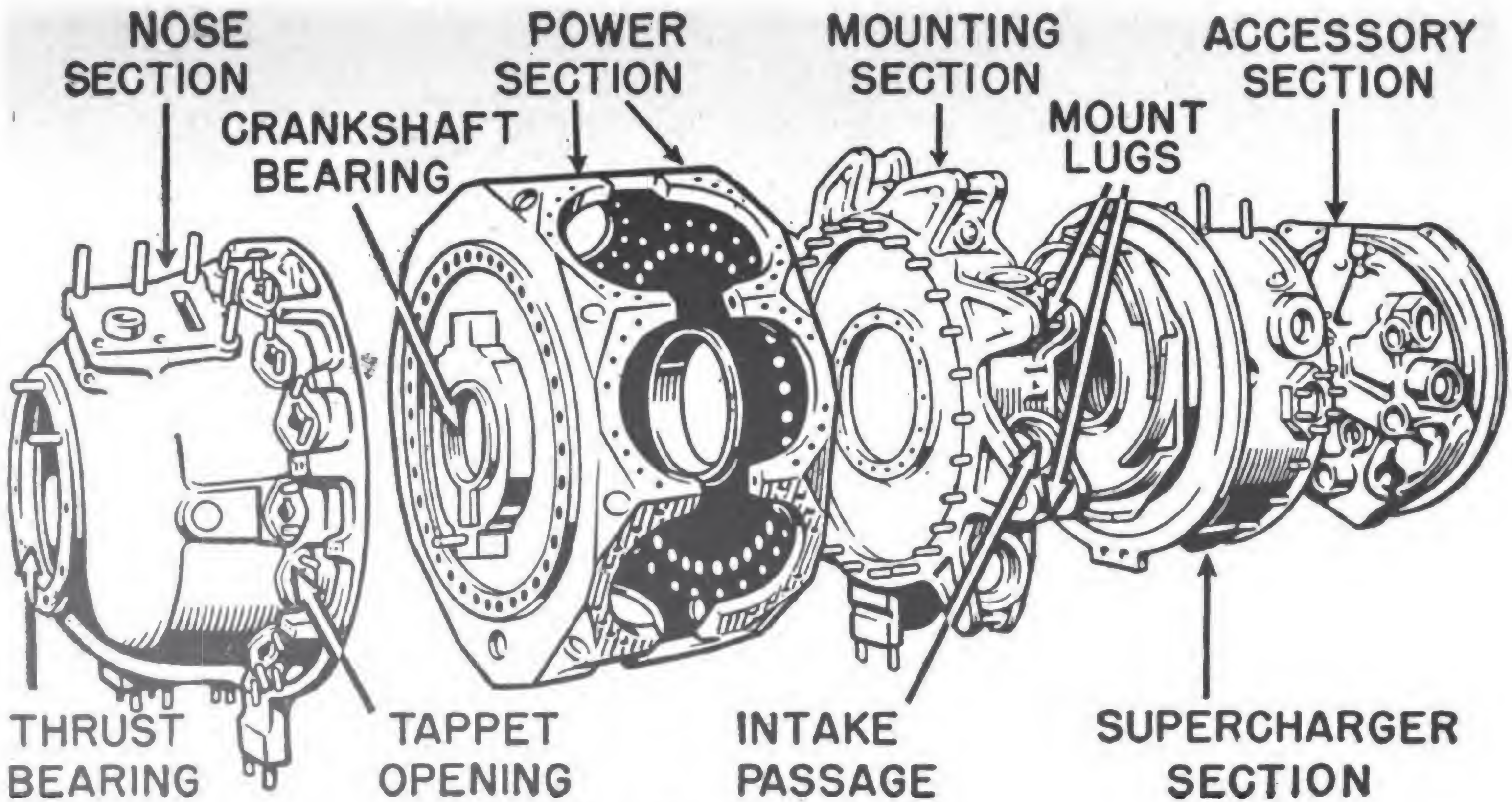


Figure 15.—Crankcase section.

In the earlier airplanes, the propeller was usually DIRECT DRIVE (fastened directly on the crankshaft) because engine speeds in those days were relatively low. As more experience was gained and the technique of vibration survey was developed, the crankshaft speeds increased progressively until nowadays a crankshaft speed of

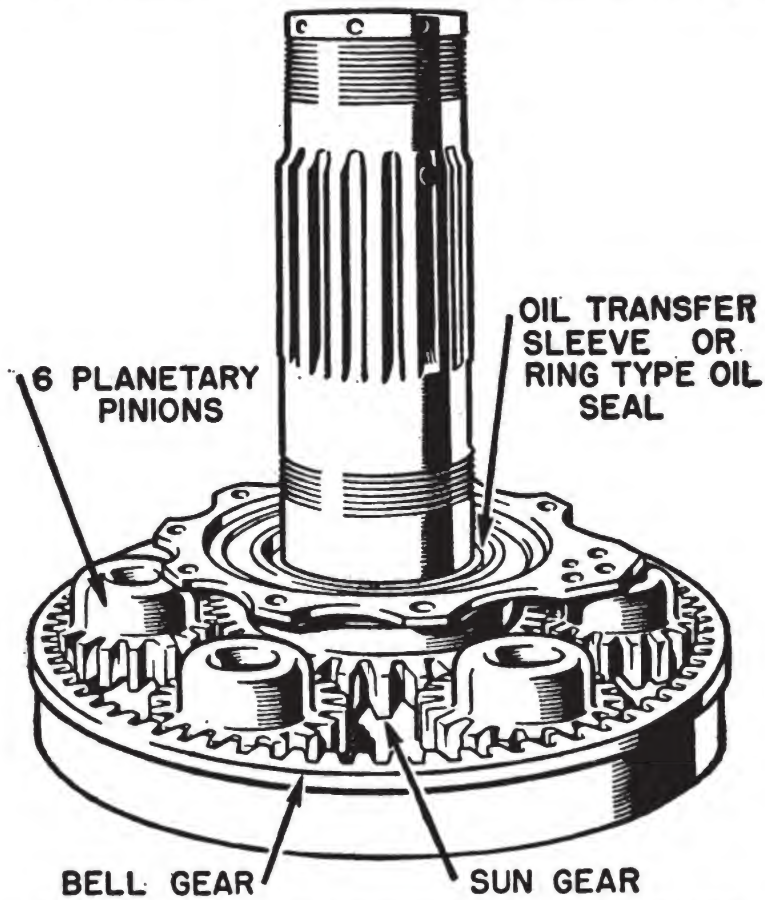


Figure 16.—Six-pinion planetary propeller reduction gear.

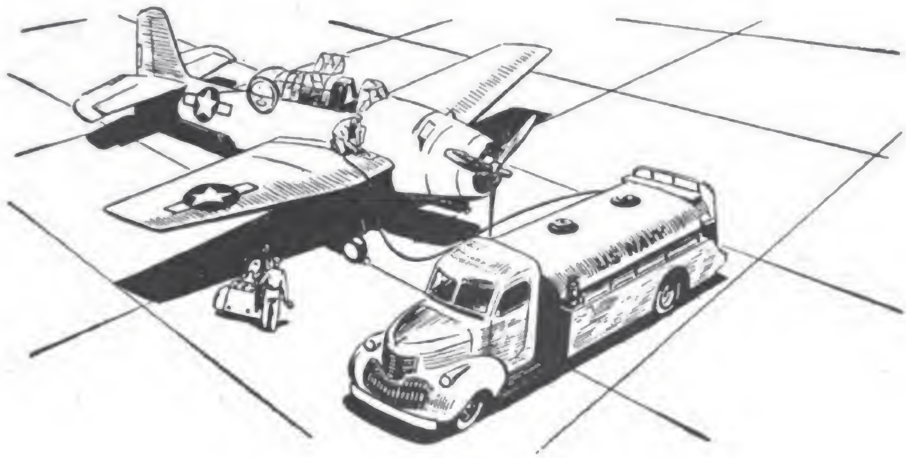
about 2,600 revolutions per minute for a large engine is not considered excessive. You'll find a few of the lower powered engines, however, which rotate as high as 3,000 revolutions per minute.

As the crankshaft speeds increased, it became necessary to provide a PROPELLER REDUCTION GEAR

in order to limit the tip speeds of long propeller blades. When you study propellers, you will learn more about this. But now it is important that you realize the desirability of limiting tip speeds, to keep the tips out of a vibration range which might cause failure.

You'll find that there are three types of propeller reduction gears which are most commonly used. These are—Single reduction SPUR gear type, FARMAN type, and the PLANETARY type.

The planetary type, such as you see in figure 16, is the one you'll probably encounter most often. Briefly, this type operates as follows—a bell-shaped gear with teeth on its inside edge (and attached to the crankshaft) drives several planetary pinions (small gear wheels). These in turn move around the rim of a stationary (sun) gear. The rotation of the planetary pinions, in turn, drives the propeller shaft and spider assembly. The propeller is attached to the propeller shaft. Because of the gear arrangement, the propeller shaft rotates at a lower speed than the crankshaft. Some of the gear ratios now in general use are 16 : 11, 16 : 7, 3 : 2, and 8 : 5.



CHAPTER 3

FUEL SYSTEM

FEEDING THE ENGINE

You've heard a good deal of talk in this war about the importance of supply lines and transportation. Military leaders have a fancy word—logistics—which they use in this connection. Actually it simply means keeping the armed forces supplied with the goods they need to knock out the enemy. Of course, as you realize, there is nothing very simple about doing this.

Nor is the problem of keeping high-powered aircraft engines supplied with gasoline a simple one. First, there is the external problem of getting the tankers through the combat zones to bring the gasoline to the air bases. But once the gasoline is available, then begins the internal problem of "engine logistics"—keeping the carburetor supplied with gasoline. The entire system, which includes tanks, lines, and accessories, is called the FUEL SYSTEM. It is a complicated arrangement, requiring careful installation, adjustment and inspection.

THE GRAVITY SYSTEM

The simplest type of fuel system is shown in figure 17 and is known as the GRAVITY SYSTEM. You can see right away the reason for the name, since the fuel flows by gravity from the tank to the carburetor. Although elementary in design, this system is still in use on various training planes. Actually, though, it isn't very practical except in a biplane or parasol monoplane. You can under-

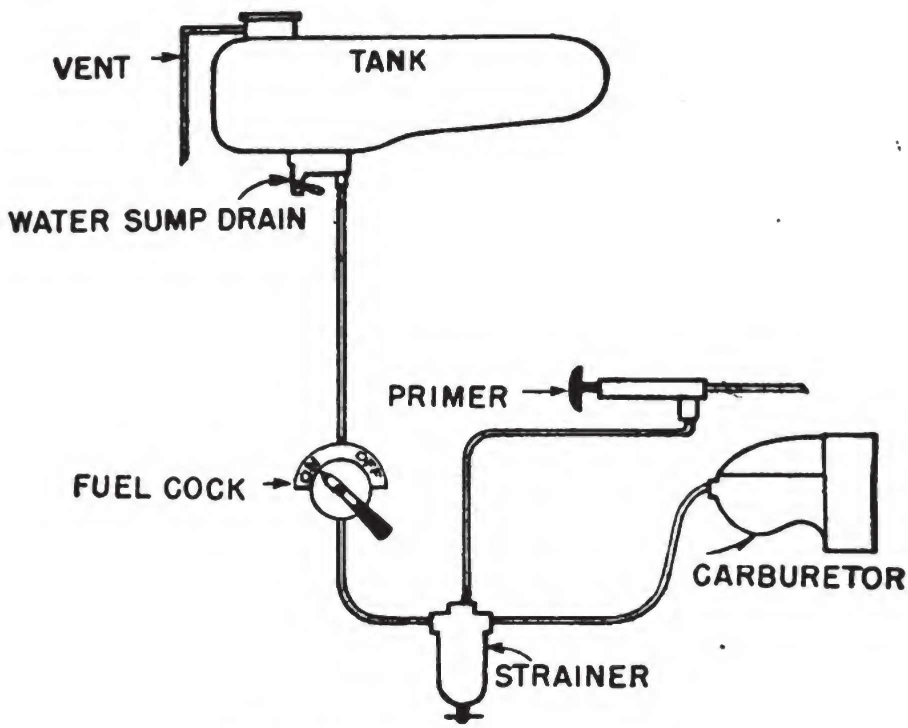


Figure 17.—Gravity fuel-feed system.

stand why, since the fuel tank must be high enough to provide a reasonable amount of pressure at the carburetor. Practically all Navy airplanes are of the low-wing or mid-wing monoplane type. Consequently, they seldom have gravity systems included in their construction.

Most fuel tanks are provided with a SUMP or a depression in the bottom of the tank. The sump collects dirt and water or other foreign matter and

keeps it out of circulation. You should make sure that the sump of any engine you are handling is drained at regular intervals and that you clean out any dirt that may have accumulated. Somewhere in the line between the tanks and the carburetor, there is also a FUEL STRAINER. This is usually a cup-like container made of aluminum alloy. It is fitted with a screen of fine wire gauze through which the fuel must pass on its way from the tank to the carburetor. Also between the tank and carburetor there must be a SHUT-OFF COCK so that the flow of fuel to the carburetor may be cut off when the engine is not running, or when it appears that there is likely to be a crash.

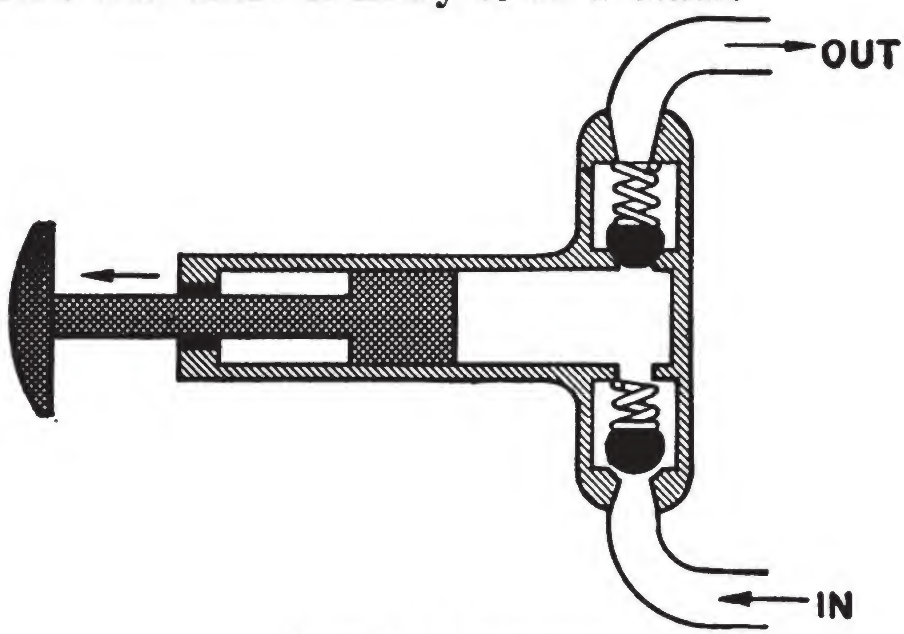


Figure 18.—Engine primer.

Another accessory is the priming pump or PRIMER which you see in figure 18. Its purpose is to draw liquid gasoline from the system and force it into several of the cylinders or to the intake manifold of the engine, in order to provide easier starting. When the engine is cold, the gasoline coming from the carburetor does not vaporize so readily as when the engine is warm. Furthermore,

the cylinders have no charge in them until the engine has begun to turn over. If a primer was not provided, a great deal of cranking would be necessary to draw gas from the carburetor, through the induction system, and into the cylinders. Actually, the primer is a small pump. When the handle is pulled back, fuel is sucked into the pump through the inlet valve, and when the handle is pushed forward, the fuel is pumped through the outlet pipe to the cylinders or intake manifold.

SIMPLE PRESSURE SYSTEM

Most fuel systems employ a mechanical pump to supply fuel from the tank to the carburetor. In such a system the tank may be below the engine, though it is best not to have it too far below. Of course, this type of system is more complicated than the gravity system, but it's the one with which you'll be coming in daily con-

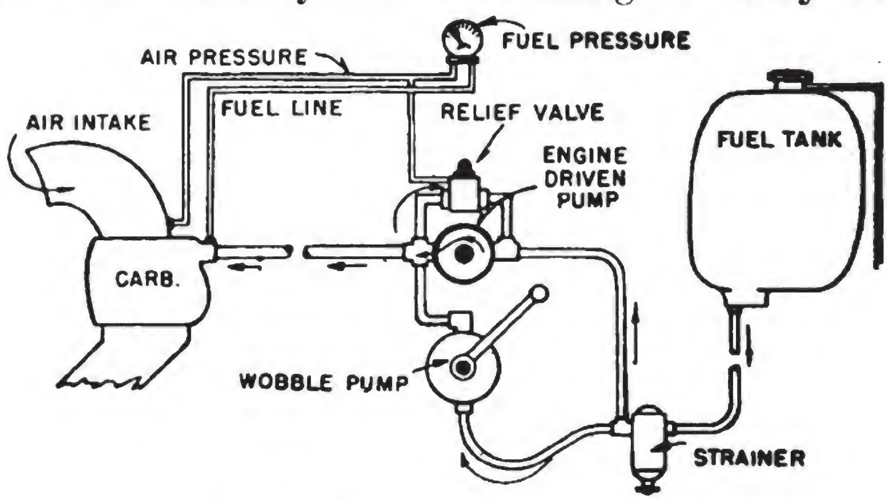


Figure 19.—Pressure fuel-feed system.

tact. Practically every Navy airplane you work on will have a system similar in principle to the one in figure 19.

If you examine this diagram, you will note that there are a number of accessories in addition to those in the gravity system. First off, there's the

WOBBLE PUMP which is really a hand pump. This supplies fuel to the carburetor for starting inasmuch as the mechanical fuel pump does not function until the engine is running. You can see, too, that it's mighty convenient to have this hand pump, in case the mechanical pump is damaged or fails to function. The hand pump is also necessary to "prime" the mechanical pump.

The mechanical fuel pump itself is operated by the engine. Usually it is mounted on the crankcase and geared directly to the engine crankshaft through a system of suitable gears. Engine-driven pumps are of two kinds—GEAR PUMPS and VANE PUMPS. The vane pump is more common at present. These pumps are capable of supplying many times the quantity of gasoline needed by the engine.

The carburetor, as you know, is a delicate mechanism, so a PRESSURE RELIEF VALVE is installed in the line between the engine-driven pump and the carburetor. The fuel pressure for carburetors (depending on the type) may range from 3 to 18 pounds per square inch. When an excessive pressure is reached, however, the relief valve opens automatically, and the fuel flows through a return line to the tank.

A small fuel line is extended from the carburetor to a PRESSURE GAGE in the instrument board. By looking at the gage you can see at what pressure the fuel is being supplied to the carburetor. If proper pressure is not maintained, the engine will stop.

SUPERCHARGERS

You're familiar with the term "thin air" as applied to atmosphere at high altitudes. Actually a given volume of air weighs less and less (has

less density) the higher the altitude. "Thin air," then, is air with a density lower than that at sea level. You can see that an ordinary carburetor would, for each revolution, take in the same volume of air, no matter what the altitude, but the weight of air taken in for each revolution would be less and less as the altitude was increased.

If means are not provided to compensate for this "thin air" condition, the horsepower of an engine will decrease rapidly with successive increases in altitude. The reason is simply that the power developed is directly dependent upon the weight of the combustible mixture in each charge of the cylinders. Now suppose the engine were supplied with a compressor that forced a constant weight of combustible mixture into the cylinders, all other conditions remaining the same. WHAT IS THE RESULT? That's it! Sea-level horsepower can be maintained at any altitude. The device that does this is called a SUPERCHARGER.

It sounds much more complicated than it really is. But if you will take a look at figure 20 and then read how the supercharger works, you should be able to understand it.

The internal type of supercharger is located in the main blower section of the engine between the carburetor and the intake manifolds. It is a centrifugal compressor driven by a series of gears attached to the crankshaft. As the mixture enters the supercharger from the carburetor, it is caught by an impeller. The impeller is a centrifugal fan which catches the mixture on its blades. It flies off the impeller blades into the diffuser (the section surrounding the impeller). The speed with which the mixture is thrown off the impeller rams it into the diffuser, where pressure is built up. In other words VELOCITY ENERGY imparted to the charge is converted into PRESSURE ENERGY. The

pressure, you see, is increased by decreasing the velocity of air without decreasing the amount of air. From the diffuser vanes, the mixture enters the distribution chamber and is carried to the cylinders by individual intake pipes.

You can see, though, that the performance of the supercharger is limited by impeller tip speeds. You'll find that the ratio of the impeller relative to crankshaft speed varies from about 6:1, which is standard, to 10:1, or high ratio, depending on the engine with which you are working.

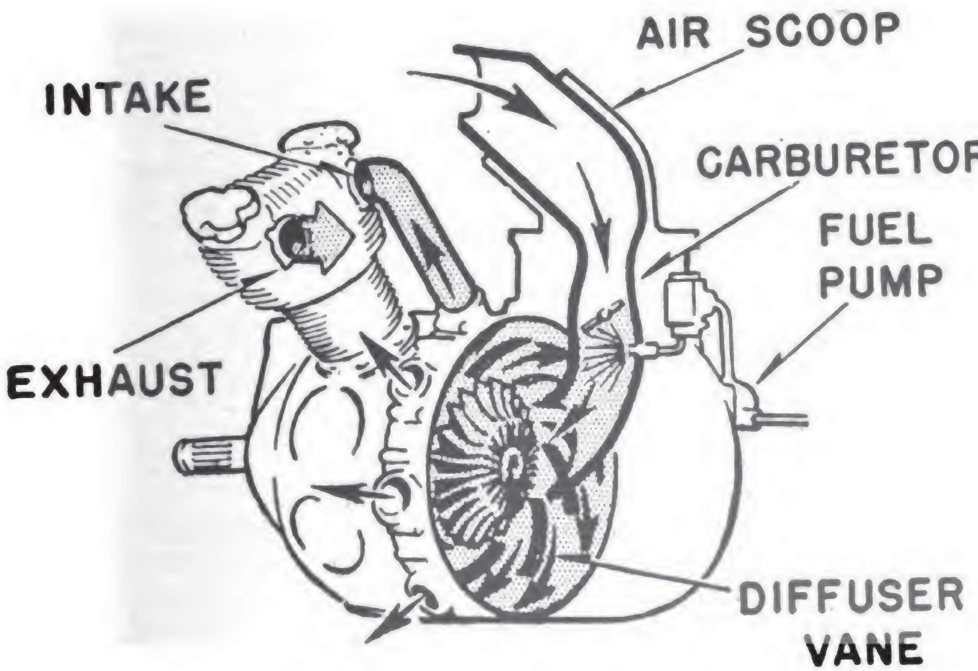


Figure 20.—Internal supercharger.

Internal superchargers are of the following types.

SINGLE-STAGE, SINGLE-SPEED

SINGLE-STAGE, TWO-SPEED

TWO-STAGE, TWO-SPEED.

The single-stage, single-speed supercharger consists of a centrifugal blower or impeller installed in the diffuser section. The ratio of the impeller

relative to crankshaft speed is always the same on the single speed supercharger. On the other hand, a single-stage, two-speed supercharger has both a low-ratio drive used for take-off and lower altitudes, and a high-ratio drive for higher altitudes.

The two-stage, two-speed supercharger has the centrifugal impeller installed in the diffuser section in the conventional manner, and another similar gear-driven impeller ahead of the carburetor. You can follow the various steps in this

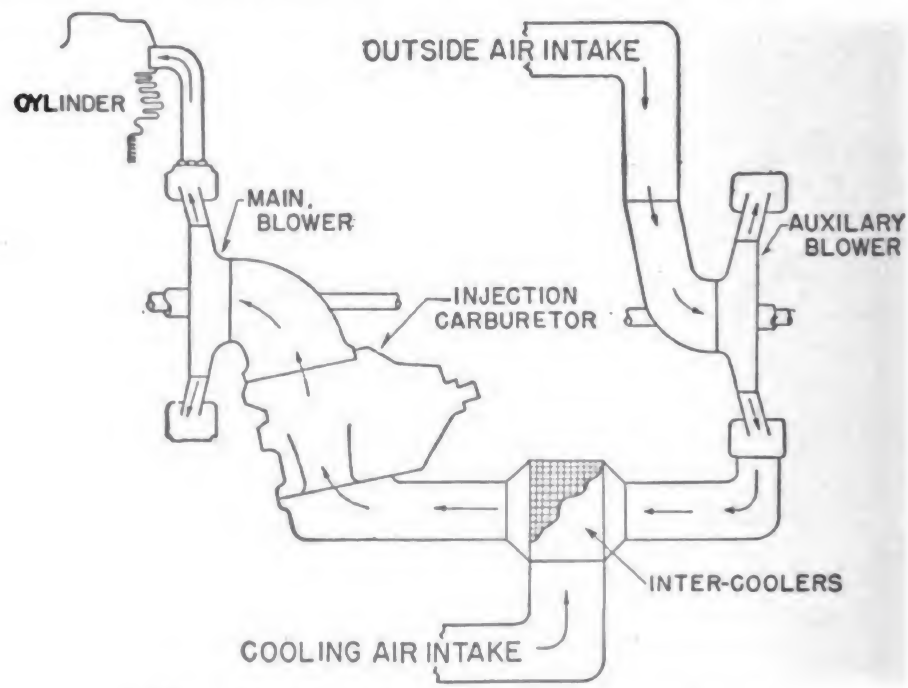


Figure 21.—Two-stage supercharger arrangement.

type of supercharging by looking at figure 21. The engines you work on will use the low-ratio speed and first stage up to about 8,000 feet, where the high-ratio speed helps out. Somewhere between 15,000 and 20,000 feet, the second stage assembly goes into action, thus keeping the engine at high efficiency despite the high altitude.

The high pressures created by supercharging bring another problem, though. Remember how

the barrel of a hand pump got hot when you were especially energetic about pumping up a tire? Supercharged pressures also result in heat in the same way. Consequently, it's necessary to have an INTERCOOLER between the first and second stages to hold the inlet air temperature within reasonable limits. An intercooler is like a liquid cooling radiator, except that air going into the engine passes through the core. The outside of the core is so located in the slip stream that the cool air passing through the honeycomb will cool the compressed air on its way to the engine.

THE TURBO SUPERCHARGER

There's another form of supercharger arrangement which you'll be running into so you'll need to know about it. It is an arrangement in which the engine is equipped with a conventional single or two-speed (ratio) supercharger and also an auxiliary exhaust turbine supercharger ahead of the carburetor. The first stage is driven by the engine but, at the critical altitude, the second stage, which is exhaust driven, is used.

Roughly, the turbo-drive consists of a wheel with vanes, on which the pressure from the exhaust gases acts. The vanes turn like those on a windmill. The speed of the wheel is controlled by a waste gate, which is operated automatically through the supercharger regulator.

CARBURETION SYSTEM

Probably you have heard of DUST EXPLOSIONS, which occasionally occur in coal mines, in grain elevators, or storage bins. You know, too, how difficult it would be to ignite a lump of coal with a match, although the coal will burn in a furnace.

But, when coal has been powdered into dust, it may be highly explosive.

On the other hand, gasoline is thought of as an explosive liquid, yet it CAN BE BURNED in a lamp or even in an open pan without explosion. BETTER NOT TRY IT, THOUGH! If the gasoline is finely divided, as in a spray, however, or in what might be termed "gasoline dust," it will burn so rapidly that the action may be considered to be an explosion. The reason is that much more of the gasoline's surface is in contact with the air when it is broken into thousands of tiny droplets (atomization). Hence more oxygen in the air, which supports combustion, comes in contact with these droplets, and more rapid combustion results. That is the purpose of the carburetor—TO TURN THE GASOLINE INTO VERY SMALL PARTICLES AND MIX THEM WITH AIR.

Carburetion may be defined as the atomization and mixing of a liquid fuel with air, in the correct proportions to satisfy the requirements of an internal combustion engine under all operating conditions. Air itself is a mixture of gases containing by weight 21 percent oxygen, 78 percent nitrogen and 1 percent other gases. Only the oxygen is utilized in combustion, since nitrogen is an inert gas and has no chemical effect on combustion. Therefore, a tremendous amount of air is consumed by a power plant. For example, an engine producing 1,500 horsepower consumes approximately 5 tons of air, or five times its own weight, for every hour of operation. The ratio of the weight of the fuel to the weight of the air consumed is known as the FUEL AIR RATIO, or THE MIXTURE RATIO.

The modern aircraft carburetor is a highly developed unit and should be treated as a fine precision device. There are three general types.

The simple FLOAT type, used on smaller engines.

The DIAPHRAGM type, used on large engines and often referred to as "non-icing" (although it is actually only anti-icing).

The INJECTION type (also used on the larger engines and also anti-icing), in which the gasoline is sprayed by pressure into the passage leading to the supercharger and from there to the cylinders.

In order to understand engines, you need to know how carburetors work and the basic principles of their construction.

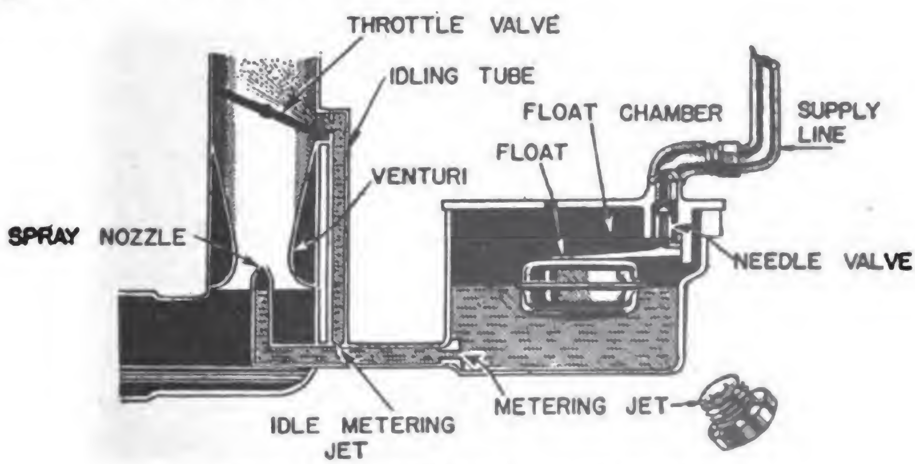


Figure 22.—Simple float type carburetor.

THE SIMPLE FLOAT TYPE CARBURETOR, shown in figure 22, receives the gasoline through a supply line (copper or aluminum alloy tubing) from the tank. This feed line leads to a connection on the carburetor bowl, or FLOAT CHAMBER. The level of the gasoline in the float chamber must be exactly right, or else the fuel will run out the spray nozzle when the engine is not running. Consequently, a NEEDLE VALVE is placed at the point where the gasoline enters the float chamber. As long as the level of the gasoline is too low, the float hangs down and allows the needle valve to drop with it.

This opens the passage from the fuel line into the float chamber, and the gasoline flows in. As the level of the fuel rises, the float rises with it, raising the needle valve, until finally the opening into the float chamber is closed. As the fuel is drawn into the cylinder, the level drops and so does the float. This opens the passage again and allows more fuel to run in. The process continues as long as the engine is running.

Now the gasoline and air must be mixed in the proper proportions, usually about 15 parts of air (by weight) to 1 part of gasoline. To measure the amount of gas supplied, a METERING JET is placed in the passage that leads from the float chamber to the nozzle. After the gasoline passes through the metering jet, it flows into the spray nozzle in the throat of the carburetor. The spray nozzle is mounted in the center of a VENTURI tube (venturi meter). (A venturi tube looks like two cones with the small ends placed together). As the air is drawn in through the air horn by the downward movement of the piston in the cylinder, it must pass through the venturi tube. The effect of the venturi tube is to reduce the air pressure to a minimum at its narrowest point. This lowered pressure draws the gasoline out of the spray nozzle and at the same time helps to vaporize it.

Of course, if the carburetor had no additional parts, the engine would run, BUT at full speed all the time. To control the engine speed, or rpm, the amount of the mixture drawn into the cylinder must be limited. This is done by means of a BUTTERFLY VALVE, called the throttle valve, in the throat of the carburetor. When this valve is closed, no mixture can be drawn from the spray nozzle up into the engine. If you regulate the setting of this valve with the throttle handle in

the cockpit, you can control the rate at which the engine revolves.

You can see, however, that some system is necessary to keep the engine idling with the throttle closed or practically so. Consequently an IDLING BYPASS is used. An IDLING JET in the passageway that leads from the float chamber to the spray nozzle allows a small amount of gas to pass into what is known as the IDLING TUBE. This tube opens into the throat of the carburetor above the edge of the butterfly valve in its closed position. Enough fuel is drawn from the idling tube to keep the engine running at slow speed.

All carburetors are also equipped with either an accelerating pump or accelerating well. When the throttle is opened quickly, the pump discharges an additional quantity of fuel into the carburetor air stream. This furnishes an extra supply to balance the added amount of air drawn in by the sudden opening of the throttle.

Since the density of the air decreases with altitude, the weight of a given volume of air also decreases. As you now know, only a certain volume of air can be drawn into the cylinder. Unless some provision were made to reduce the quantity of gasoline supplied, the result would be a mixture containing too much gasoline for the available air.

Carburetors, therefore, are equipped with some means of controlling the amount of gasoline supplied. One method is to put another needle valve (operated by the pilot) in the metering jet. Another is by lowering the pressure of the air in the float chamber. This is done by means of a passageway from the venturi tube to the float chamber. The passage is opened as the

density decreases with the increase in altitude. Thus the quantity of gasoline supplied is reduced, so that there is not too much gasoline for the amount of available air.

Leaner mixtures are desirable for maximum economy at cruising speeds, as you know, while a much richer mixture is necessary for maximum power at full throttle. ECONOMIZER SYSTEMS take care of this situation by uncovering another jet when the throttle is opened wide. As the throttle valve is closed, the economizer valve, regulating the flow through the jet, is closed by a spring. Thus at the cruising position of the throttle, the flow of fuel through the jet is completely shut off.

DIAPHRAGM CARBURETOR

A pressure carburetor differs from the more commonly used float carburetor in that it is controlled entirely by diaphragms (membrane-like partitions). The control of the air passage is accomplished by a variable venturi meter rather than by a butterfly throttle valve and fixed venturi, as in the float carburetors. The main fuel valve in this type of carburetor is operated by two diaphragms. These form a chamber between them which is filled with fuel under pressure. The outside of the chamber is connected by a passage to the venturi section of the carburetor.

From what you've read already you know that the air at the venturi throat has a lower pressure than at any other point and hence is sucked through connecting tubes at that point. If the engine is running slowly and little gas is required, the diaphragms are drawn away from each other by the action at the venturi. And the valve which admits the fuel is almost closed. At high engine

speeds there is little difference in pressure in the venturi, and the diaphragms are allowed to move back toward each other. This forces the gas between them into the engine. It also opens the valve to admit more fuel. Since the chamber is completely filled with fuel at all times and the system therefore is not affected by gravity, the carburetor will function in any position. It is not affected by acceleration forces.

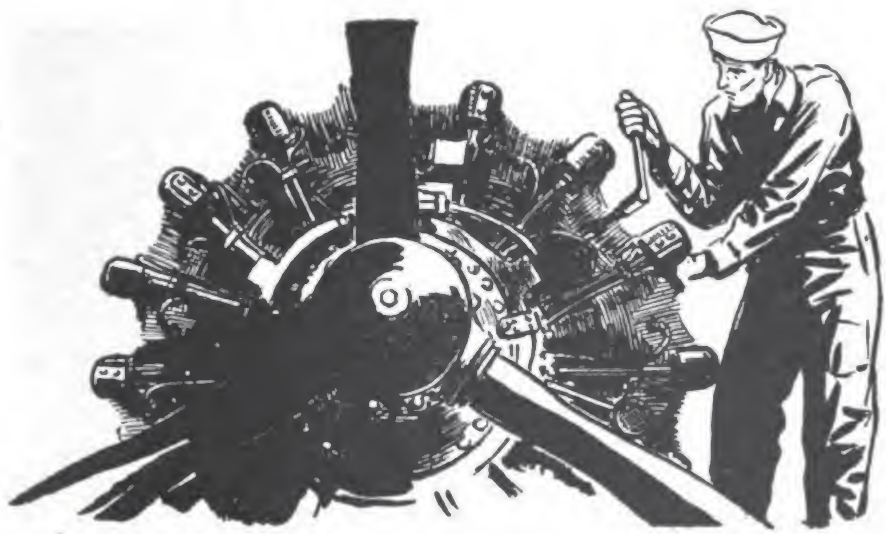
The variable venturi is formed by two throttles of approximately cylindrical shape. They are located on opposite sides of a rectangular duct and are geared together. As the opening between them is varied, an almost perfect venturi shape is preserved at all times. This feature helps to keep this type of carburetor free of icing trouble.

INJECTION CARBURETOR

The injection carburetor employs a closed fuel system from fuel pump to discharge nozzle. The fuel spray is atomized under positive pump pressure and metered according to the venturi air suction. When the engine is running, the suction created at the throat of a small venturi is a measure of the amount of air taken into the engine. When corrected for changes in air density by an automatic mixture-control unit, it becomes a measure of the mass air flow, and is applied to an air diaphragm to regulate the fuel-metering pressure. This air flow is controlled by butterfly valves, which are synchronized to open and close together and are operated by a throttle-control lever. A regulator unit automatically adjusts the fuel flow and pressure across the metering jets in proportion to the air flow through the throttle body.

The basic principle of this type of carburetor is summarized as follows—

Air is taken into the carburetor through an AIR SCOOP. This air flows through the throttle body, where the volume is controlled by the butterfly valve in the air passage. The flow of air through a booster venturi and a large venturi (located in the air passage) controls the fuel metering force in the regulator unit by the pressure difference between the throats of the venturi and the air scoop.



CHAPTER 4

IGNITION SYSTEM

IT'S DYNAMIC

From your study of the four-cycle internal combustion engine, you know that it is necessary to produce a spark to ignite the compressed gases in a cylinder. You know also that the spark is TIMED to jump across the points of a spark plug for this purpose.

But how is this electrical energy produced, stepped up and distributed?

The IGNITION SYSTEM is the answer. It includes the means of producing the necessary high-tension current, the wires for conducting the electricity to the spark plugs, the spark plugs themselves, shielding to prevent interference with the radio, and switches with which to turn the system on or off. Some ignition systems employ a battery. But you'll find that most ignition systems use high-tension magnetos, with built-in distributors, from which a current is led directly to the spark plugs.

In order to understand how the ignition system

of an airplane engine works, however, you first need to be clear on a few fundamentals. If you know electricity, you know that electricity in motion is DYNAMIC ELECTRICITY. It is easily generated, stored, and controlled. That's why it is used exclusively in electrical installations and equipment.

CIRCUITS

Dynamic electricity has the power to move or flow from an object of high potential to an object of lower potential, or from positive (+) to negative (−). The greater the difference in potential, the greater will be the pressure or force causing the electricity to flow. The electrical path that is followed by a current is called a CIRCUIT.

The use of a battery is based on this principle. If you attach a wire conductor to the two electrodes of a battery, the electricity flows through the wire and the battery making a continuous or CLOSED CIRCUIT. Further, if you put a switch in this conductor, you can open the switch and create an OPEN CIRCUIT in which the flow is stopped.

There is also another type of circuit known as a GROUNDED CIRCUIT. In this type the wire conductor does not form a continuous path for the circuit, but ends in a common conductor, such as the earth—or in the case of an airplane, the metal framework.

MAGNETIC INDUCTION

In airplanes, the MAGNETO is the nucleus of the ignition system, although, of course, the entire system is made up of various circuits and switches. The magneto itself is a device for generating an electrical current by cutting the lines of force in a magnetic field.

Here's a simplified explanation of the principles upon which the magneto operates. An invisible force, known as magnetism, affects iron and steel, setting up lines of force about them. The area in which the magnetic force acts is called the magnetic field. This field appears to be made up of lines of force which flow from the north pole to the south pole of the magnet. If a coil of wire is moved through these lines of force so that it cuts

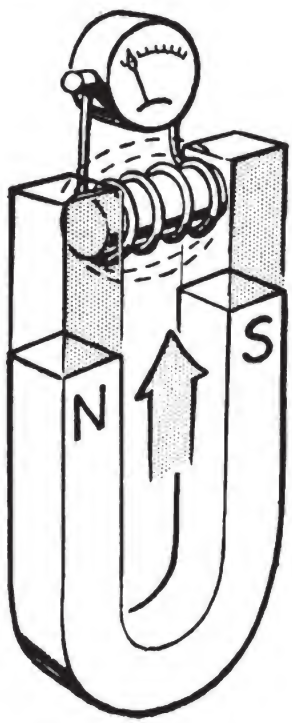


Figure 23.—Magnetic induction.

them, an electrical current will flow through the coil. Such a current is called INDUCED CURRENT. If you move the magnet, you get the same result, as is shown in figure 23.

The "current" of magnetism is often referred to as the MAGNETIC FLUX. Flux means flow, and hence the words "magnetic flux" means simply the flow of magnetism from the north to the south pole. If the north pole of the magnet is brought

near one end of the core (a bar between the two poles) and the south pole near the other end, the flow will be from north to south. If the magnet is turned halfway around, so that the north and south poles of the magnet are reversed, the magnetic flux will travel through the core in the opposite direction. As the magnet is rotated, the magnetic field around the core is built up from zero to a maximum and then back to zero again, as the magnet takes the position in which its two poles are at equal distances from the ends of the core. Thus, as the magnet is rotated, the magnetic field is constantly being built up and then dropped to zero.

Since the magnetic field expands outward from the core, this building up and collapsing of the field provides the relative motion between the magnet and the coil of wire which is necessary to induce a current in the coil. This current is called a PRIMARY CURRENT, and the coil is called a PRIMARY COIL.

THE MAGNETO

In the type of magneto used on aircraft engines, the magnets move or rotate between arms of a U-shaped core. The coil is wrapped around the horizontal part of the U. As the poles of the magnets are brought close to the arms of the U-shaped core, the core is magnetized, and a magnetic field expands out from it, cutting the coil and inducing a current in it.

The secondary, or high tension, current is produced by surrounding the primary coil with an outer or SECONDARY COIL. Now, as the current changes in the primary coil, the magnetic field around the coil also changes. As this field builds up and collapses, there is a relative motion be-

tween it and the secondary coil. This induces a current in the secondary coil. The magneto-electric machine just described is a MAGNETO. It is a self-contained unit driven by the engine and used to generate the high-tension current used in the ignition system.

The voltage from the secondary coil can be increased the desired amount by having a large number of turns of fine wire in the coil. In the aircraft magneto many thousands of turns of VERY FINE WIRE are used, and for compactness the secondary coil is wound around the primary coil.

If you want to increase the voltage, you merely make the magnetic field move faster so that it cuts the wire more quickly. This is accomplished by putting a CIRCUIT BREAKER in the circuit of the primary coil. The circuit breaker will turn the primary current on and off very rapidly, thus making the magnetic field collapse more quickly.

In the magneto, the circuit breaker consists of two contact points called BREAKER POINTS, which are forced apart by a cam on the magneto shaft, thus breaking the primary current. If the primary current is broken when the magnetic field is at its maximum, a surge of high-tension current occurs in the secondary coil. At the same time, the primary current attempts to jump, or arc, across the gap between the breaker points. Unless something were done to prevent this action the points would soon burn off and faulty operation would result.

Like the valves, magnetos are TIMED so they will furnish sparks to the cylinders in the proper firing order. This IGNITION, or MAGNETO TIMING, of an engine is arranged at the time of magneto installation.

To prevent this arcing action, a device called a CONDENSER is connected across the breaker points. The condenser acts as a "shock absorber," or storage tank, to save up the surge of primary current and prevent its jumping across points. The current will not pass through the condenser from one side to the other. But, when the primary current is reversed (by reversing the poles of the magneto), the current which is stored up in the condenser flows back into the primary coil and

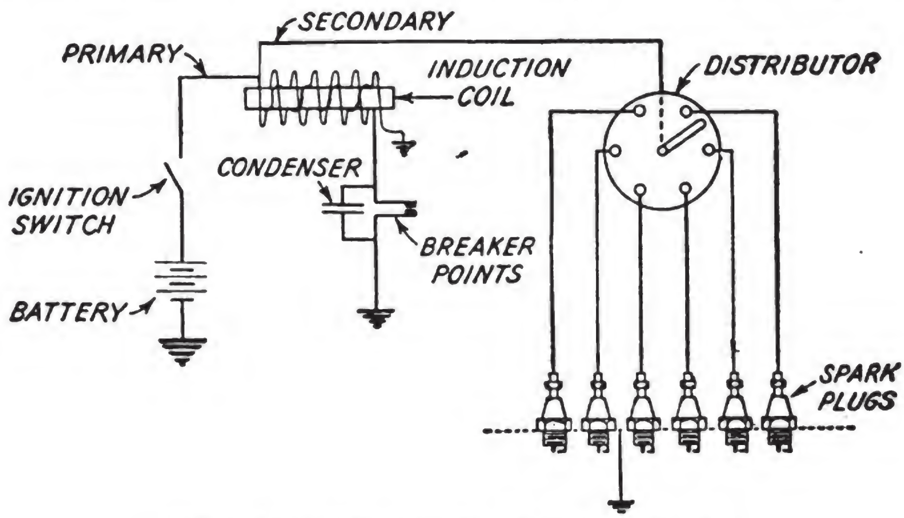


Figure 24.—Distributor for six-cylinder engine.

thus adds to the current being built up in the primary by the spreading out of the magnetic field. The condenser consists of alternate layers of material that will conduct electricity and layers of insulating material.

Now you have sufficient voltage to make a spark. But this spark must occur at the proper time. The particular moment, you'll recall, is when the piston is near the top of the cylinder on the compression stroke. A DISTRIBUTOR, so named because it distributes the current separately to each plug at the proper time, is therefore used. A diagram of the distributor arrangement for a six-cylinder

engine is shown in figure 24. One end of the wire from the secondary coil is connected to the revolving arm in the distributor. This revolving arm is called the ROTOR. Contact segments are equally spaced around the insulated distributor block. Each segment is individually connected to a spark plug in every cylinder. As the distributor finger brushes past a contact segment, the breaker points are timed to open. The high-tension current in the magneto is conducted directly to the spark plug which is connected to that segment, or contact point, through the ignition harness.

IGNITION HARNESS

An IGNITION HARNESS (fig. 25) is an assembly of electric cables and terminals enclosed in a

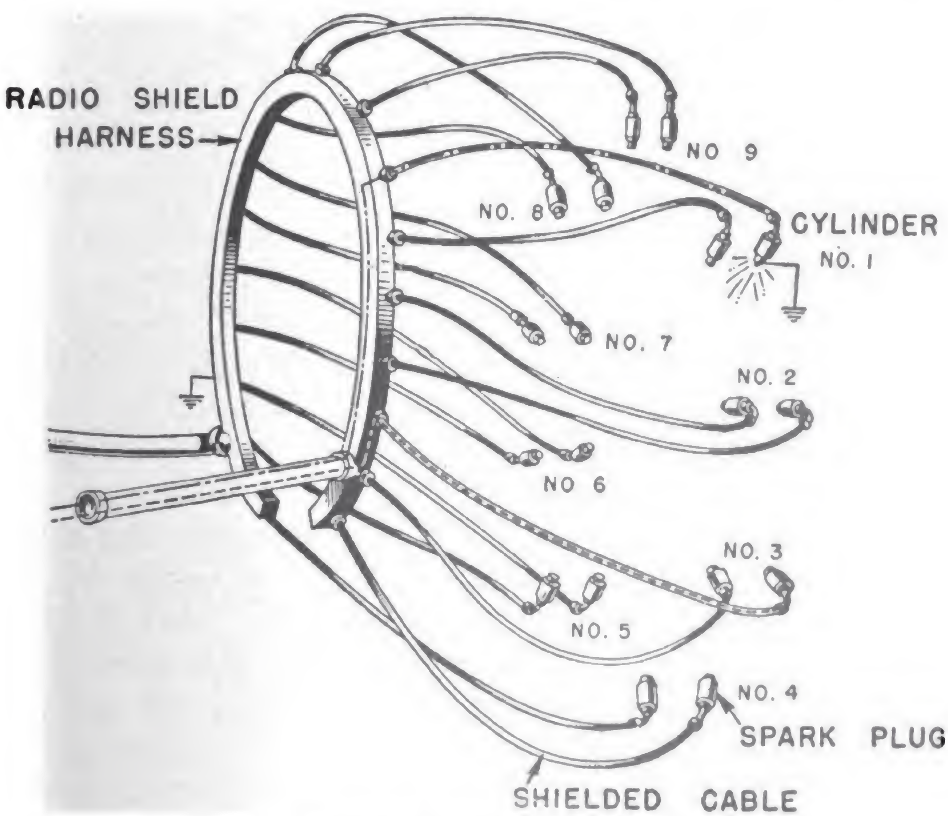


Figure 25.—Ignition harness.

MANIFOLD for use in the ignition system of an engine. Both high-tension and low-tension wiring are employed. The high-tension cables are made of many small wires twisted together and heavily insulated with cord and rubber. They are used in the high-tension circuits, such as the circuit from the booster to the distributor and the circuit from the distributor to the spark plugs. The low-tension cable is composed of fewer twisted wires, which are of lighter weight and are less heavily insulated. Low-tension wire is used in the ground circuits.

Manifolds, or looms, are used as conduits for the cables. They are made of aluminum or stainless steel tubing. For radial engines the manifolds are usually in the form of a hoop or two halves of a circle. And for in-line or V-type engines, they are often U-shaped. By this means the cables are protected from burning as a result of the heat of the engine, from abrasion caused by vibration, and from deterioration caused by oil and grease.

An electromagnetic field surrounds ignition cable each time a discharge of current passes through it. If the cables were merely rubber-covered, this disturbance would ordinarily be picked up by the radio receiving set and could cause interference. In order to prevent this interference, all ignition cable is enclosed in metal housings or manifolds. Any exposed portions are covered with braided metal casings. In fact, on aircraft equipped with radio, the entire ignition system is shielded to insure adequate reception of signals. All shielding must be firmly grounded so that the electrical energy absorbed may be dissipated properly. Magnetos and spark plugs are also thoroughly shielded to prevent radio interference.

IGNITION SWITCH

A wire is connected to the end of the primary coil and run to the switch in the pilot's compartment. This switch eliminates the effect of the breaker points by leading the current around the points. This arrangement prevents the formation of high-voltage current because the opening of the breaker points does not break the primary current and hence has no effect. Since there is no high voltage current, the spark will not jump across the plugs and the ENGINE STOPS. An INDIVIDUAL SWITCH is used to connect and disconnect the ignition system of each engine in an airplane. On multi-engine airplanes, however, a MASTER SWITCH is used to shut off all engines in case of emergency.

If the wire to the primary coil becomes disconnected from the switch, the engine won't stop when you turn off the switch. And in this connection, you'd better take special note of the fact that, IF THE WIRE IS DISCONNECTED, THE SWITCH WILL NOT AFFECT THE MAGNETO AND THE ENGINE CAN START AT ANY TIME, REGARDLESS OF THE POSITION OF THE SWITCH. Thus, if the wire is broken or disconnected from the ground connection on the switch, or from the connection to the engine frame, any accidental movement of the propeller might start the engine. You'll agree that this is a highly dangerous situation.

SPARK PLUGS

Although the spark plug is a small part of the aircraft engine, it plays an important role. This device starts the combustion process. Furthermore, it is called upon to perform its duty at any instant and under extreme temperature variations. There are two types of spark plug which

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you'll find in common use—those with porcelain or ceramic insulators and those with mica insulators. The mica plug is used most widely on aircraft engines. But the Navy is now using ceramic plugs on certain engines, such as the R–2800–8 which powers the Corsair Fighter.

The two principal members of the ordinary mica-type spark plug are the "CORE" and the "SHELL." In figure 26, the shell is shown by section lines in the diagram at the left of the illustration. The core includes a center electrode, or spindle, made of steel and copper. The steel provides strength, while the copper promotes heat transfer. Surrounding the electrode is a mica "cigarette," which, together with the mica washers protecting it, insulates the electrode from the remainder of the spark plugs. These washers, forming part of the nose, are held firmly in place by a brass core wedged into the body of the plug. The shell, which may or may not be finned, has its own set of electrodes and is attached to the core by means of threads. An assembly gasket is employed to prevent gas leakage from the cylinder. Four different types of mica spark plugs are also shown in figure 26.

The ceramic-type spark plug, which you see in figure 27, uses a baked-clay-type insulator which is made from various clay and mineral rock deposits. The raw material is ground into a powder, mixed with the necessary binder, formed and baked at a high temperature. The spindle, an alloy wire with the terminal at one end and the center electrode at the other end, passes through the center of the insulator. The whole assembly is clamped into the shell by means of a packing nut. The side electrode is riveted or welded into the shell. The shell is threaded and screws into the cylinder. The lower part of the insulator, which

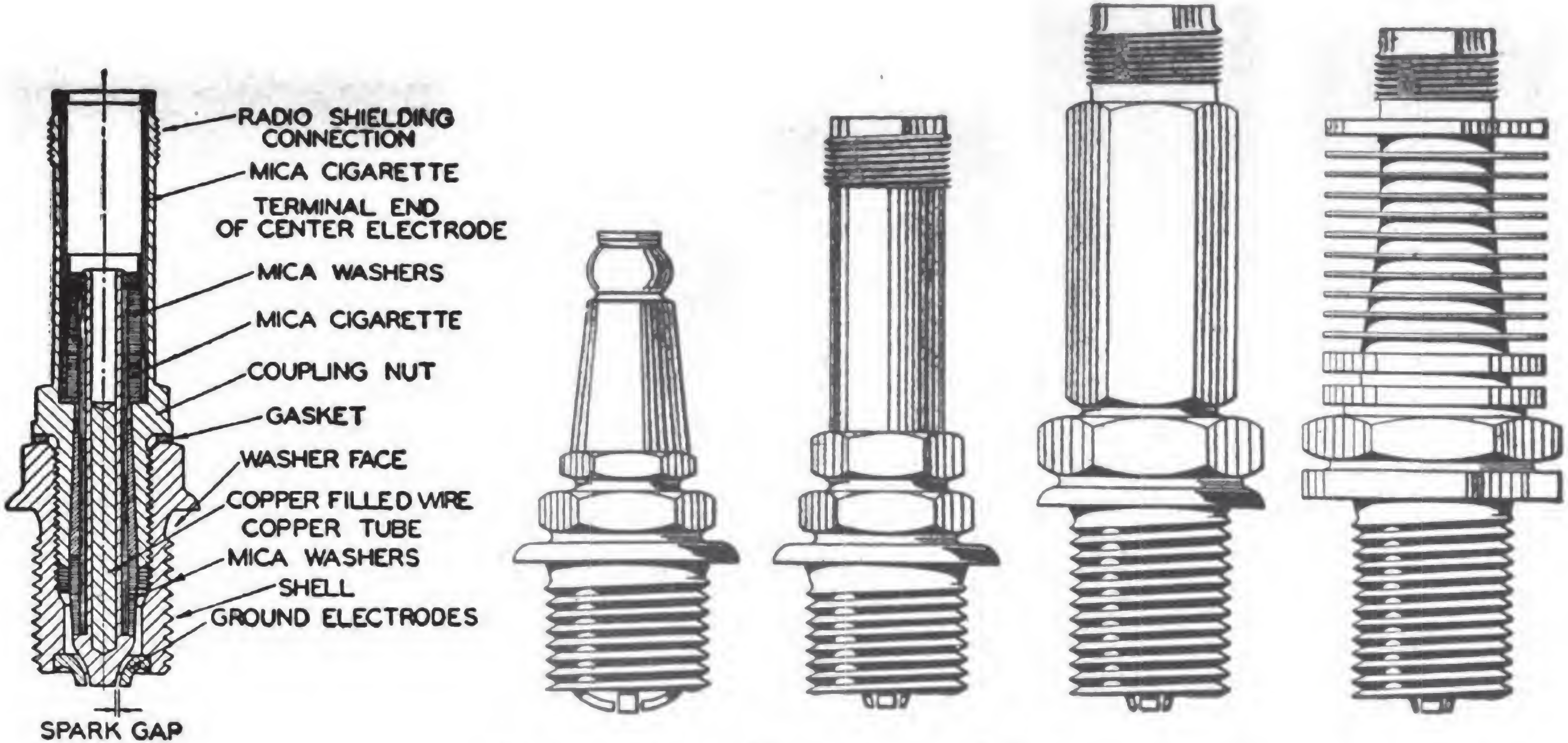


Figure 26.—Parts and types of mica spark plugs.

is exposed to the heat inside the cylinder, is known as the core and serves as the temperature control.

The current flows from the plug's terminal, at the end of the inner electrode, down to the lower end or point of the inner electrode, and then jumps from this point to the point or points on the shell. In jumping the gap between the points, the current produces the spark that ig-

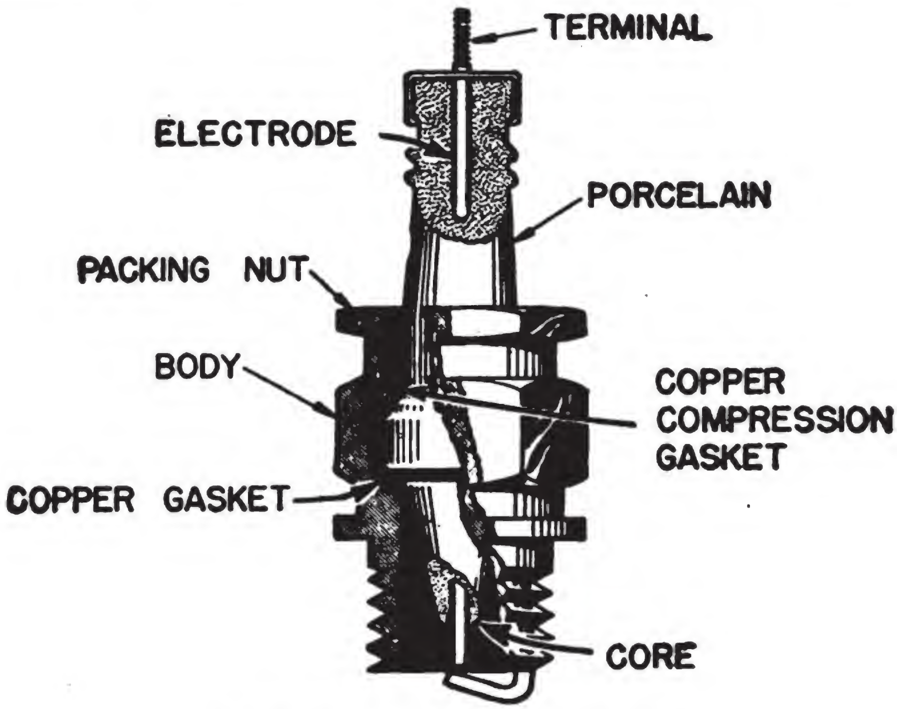


Figure 27.—Ceramic-type spark plug.

nites the charge. This gap must be held to close limits in order to produce the proper type of spark.

If the electrodes of a spark plug are not lined up nearly parallel, sparking may occur at a particular spot, usually the tip of each electrode. In that case, high gap erosion in that region will result, as revealed in figure 28. Sparking takes place with equal intensity and with equal fre-

quency from each of the electrodes when they are properly set. But in the event that the gaps are not uniform, the spark will continue to jump the smallest gap.

All service type engines are provided with two magnetos and two sets of spark plugs. These provide dual ignition and consequently insure better combustion, since a charge will burn more evenly, if ignited at two points. Dual ignition is also a safety measure, for, if one magneto goes out of order, the other one will keep the engine running until repairs can be made.

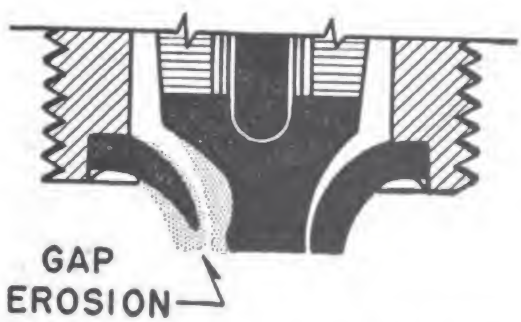


Figure 28.—Results of improper gap setting.

Spark plugs may be classified according to the length of the thread engagement into the cylinder head. This is known as a spark plug's "REACH." Thus a "short reach" plug has a short thread engagement, and a "long reach" plug has a long thread engagement.

The fundamental factor affecting the operating temperature of a spark plug is the amount of core exposure. A plug having a long exposure provides a longer path of travel for heat transfer from the spindle tip to the cylinder head. The tip is consequently maintained at a higher temperature than the tip of a plug having a short length of exposure. Since plugs having a shorter exposure provide more rapid heat transfer, they

are used in engines which operate at high temperatures. To a large extent, engine design determines the type of plug necessary for functioning within the proper heat range. Shielded and unshielded spark plugs are fundamentally the same, except that the shielded plugs eliminate radio interference from the ignition system.

CHAPTER 5

LUBRICATION SYSTEM

A COAT OF OIL

IMAGINE what would happen to an engine if the many moving parts weren't lubricated. The din of squeaks and rasps would be terrific as the various parts ground against each other. Surfaces would be rapidly worn away. The temperature of the parts would rise, dangerously expanding them. The friction would result in great loss of power. And you could very soon say goodby to your engine.

Use of a lubricant, however, coats each metal surface with a thin film of oil that moves on another surface or is in contact with a moving surface. Between the films on adjacent surfaces, other layers of the lubricant slide along on each other like the individual cards in a deck of playing cards. Thus the high friction of metal-to-metal contact is replaced by the low internal friction of the fluid oil.

In aircraft engines, the lubrication system is designed to meet the problems of friction, bearing stresses, and high temperatures. If it is to do

the job successfully in some of the engine parts, the oil pressure must be maintained constantly.

In addition to those parts lubricated under pressure, there are others, such as pistons, cylinder walls, valve mechanisms, and accessory drive gears, which are lubricated by the splash or spray of oil agitated by the revolving crankshaft and connecting rods.

Since a large percentage of engine failures can be traced to lubrication difficulties, you should be thoroughly familiar with every detail of the lubrication of engines. Before you attempt to service the lubrication system of an aircraft power plant, you should carefully STUDY THE DETAILED INSTRUCTIONS regarding its lubrication. These instructions are delivered with each new engine.

WET AND DRY SUMPS

Engines may be divided into two general types with respect to lubrication systems. These are the WET SUMP and the DRY SUMP. A sump is a pit or reservoir, serving as a drain for the oil. In the wet-sump engine the oil is carried in the crankcase, and no external tank is necessary. Automobile engines are of this type. In dry-sump engines, the oil supply is carried in a separate tank and is returned from the sump to the tank by a scavenger pump as fast as it passes through the engine.

PRACTICALLY ALL MODERN AIRCRAFT ENGINES ARE OF THE DRY-SUMP TYPE. You can see the reason for this, as it is obvious that no large amount of oil can be carried in the crankcase of a radial engine without flooding the cylinders. In the case of an in-line engine, it is desirable to keep the crankcase free of oil which would run into the cylinders in case of inverted flight or other acrobatic maneuvers. Furthermore, many of the in-

line aircraft engines are inverted with the cylinders below the crankcase. It is apparent here, too, why the oil could not be carried in the crankcase. Apart from the matter of oil storage, however, the lubrication principles of both the wet and the dry sump engines are the same.

OIL SYSTEMS

The oil system may be divided into two main parts, the EXTERNAL SYSTEM and the INTERNAL SYSTEM. Figure 29 is a diagram of a typical external

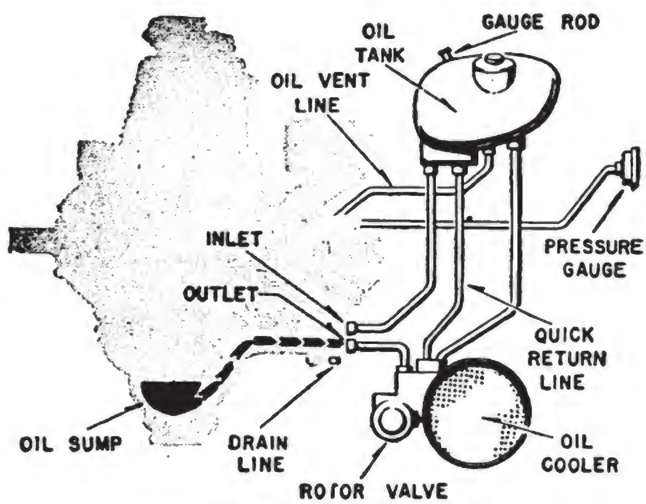


Figure 29.—External oil system.

oil system used on large aircraft engines. The oil is pumped through the engine from the tank by a powerful gear pump, mounted in the crankcase. It is pumped out of the engine by another gear pump, called a scavenger pump. Referring to the illustration, you can trace the path of the oil through the external system.

The oil tank must be constructed sturdily, and is usually made of aluminum alloy or stainless steel. It must be large enough, not only to hold all the oil required for normal operation, but to provide expansion space of approximately 10 percent of its total capacity. Allowance is thus made

for the foaming and expansion of the oil when it is heated. Oil tank capacity should provide for 1 gallon of oil for about 12 gallons of fuel in the air-cooled engine installations, and 1 gallon of oil for about 14 gallons of fuel in liquid-cooled engines. The tank must be provided with a vent pipe, which is usually led back into the engine crankcase, so that, if the oil foams excessively, any quantity that is forced out of the vent pipe will go back into the crankcase.

Since the crankcase is ventilated to the outside air through the crankcase breather, air is allowed to enter the oil tank through the vent pipe. Otherwise, oil would not run out of the tank. The tank is provided with a gage, usually in the form of a piece of metal attached to the filler cap. By removing the filler cap and noting the level of the oil on the rod which serves as a gage, you can determine the content. Before checking the quantity of oil in the tank, you should remove the rod, wipe it off with a clean rag, and reinsert it in the tank. Then you should remove it again and check the level of the oil.

From the tank, the oil passes through an AUTOMATIC OIL TEMPERATURE-CONTROL UNIT into the engine. Upon its return from the engine, it passes through the automatic oil temperature-control unit again. This unit is provided with a thermostatic valve; that is, a valve that is operated by heat. If the oil is cold, it is passed directly back into the tank and once more from the tank through the engine and back again, until it is warm. Oil that is too cold does not flow readily and therefore does not lubricate properly.

On the other hand, oil that is too hot becomes very thin and does not lubricate properly either. Accordingly, when the oil becomes heated, the thermostatic valve comes into action, and, instead

of permitting the oil to pass back directly to the tank, it is led into an oil cooler. The oil cooler is merely a radiator, commonly located in such a position that a stream of air can flow through the core and cool the oil. After the oil has passed through the oil cooler, it is brought back into the top of the tank. Cold oil, which is bypassed by the thermostatic valve, travels from the tank inlet directly into the tank outlet. Thus, when the oil is cold, only a small quantity of it is circulated through the engine, and the oil temperature is raised more quickly than if the oil were led into the top of the tank. With this method, it is not necessary to raise the temperature of the entire tankfull of oil at one time.

The DRAIN VALVE or cock is located at the lowest point of the piping between the tank and the engine pressure pump, as shown in figure 29. This permits complete drainage of the tank and engine. You should note, however, that the drain cock ordinarily does not drain the oil from the oil temperature regulator. The regulator must be drained separately by removing the plug located at the lowest point on the assembly.

There is one other important part of the external oil system. This is the OIL FILTER. As the name implies, the oil filter is simply a device to clean the oil. One commonly used type (the Cuno, figure 30) consists of a number of disks, located very close to each other. The oil must pass between the disks on its way between the engine and the tank. The disks are so close together, that any grit or dirt in the oil is screened out and dropped into a sediment bowl in the bottom of the cleaner. In some installations the space between the disks is cleaned automatically, while in others it must be done manually at frequent intervals. In small engines,

screens or finger strainers usually are located in either the oil passage or the sump. Engine service instructions will specify when these strainers

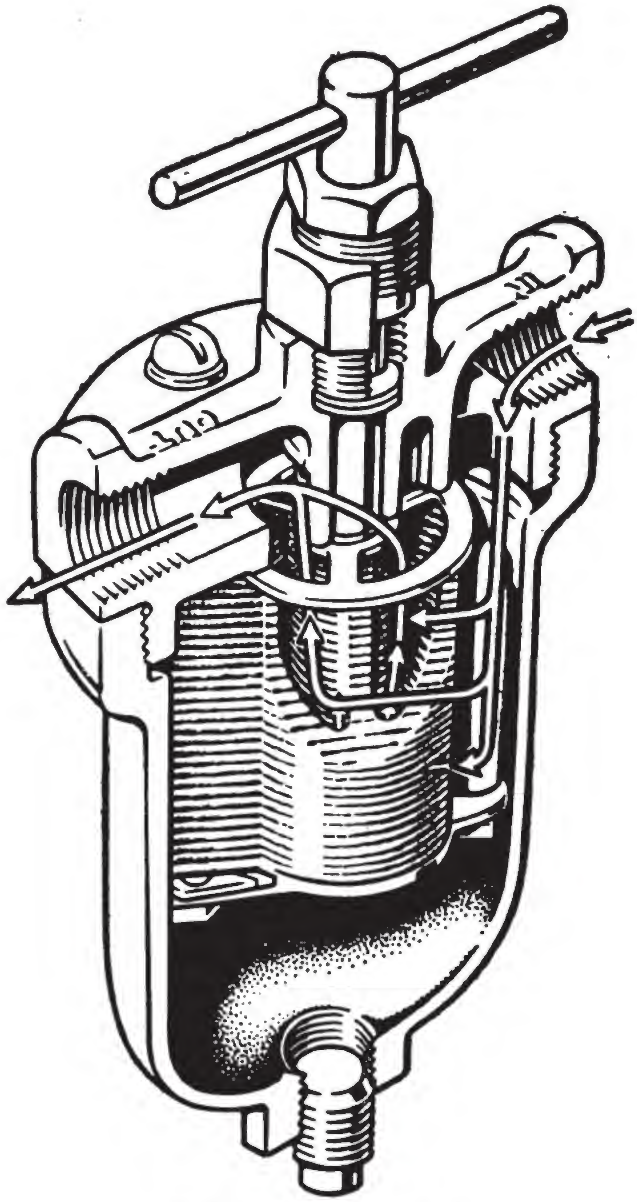


Figure 30.—Cuno filter.

should be cleaned. When an engine is about due for overhaul, you should watch it carefully to make sure the screens do not become clogged completely.

The internal oil system of an engine covers that portion of the lubrication system contained entirely inside the engine. The circulating systems in various engines are different, but the same general principles apply in all of them.

The circulation of oil through a typical in-line or V-type engine is illustrated in figure 31. In the PRESSURE PART OF THE SYSTEM the oil enters the pump (*A*), which forces it through a screen or strainer (*B*) and distributing pipe to each of the crankshaft journals. From the rear crankshaft journal the oil is forced to the hollow camshaft (*C*), which furnishes lubrication to the overhead valve mechanism. A pressure line leads from the front crankshaft journal through an oil-control valve (*D*) to a connection (*E*) for operating an hydraulic, controllable-pitch propeller. In geared engines, a pressure line leads to the propeller-shaft reduction gear. The oil-pressure relief valve (*F*) is adjusted to obtain the desired pressure in the system, shunting surplus oil to the intake side of the pressure pump.

The oil which is forced into the crankshaft journals is thrown by centrifugal force (whirling away from the center) to the crankpins and connecting-rod bearings. The dotted arrows designate oil thrown out at various points in the pressure system. This oil lubricates by splash or spray such parts as pistons, rings, cylinder walls, valves, tappets, accessory drive gears, and bearings before draining into the scavenging sumps.

Two scavenging pumps (*I*) are shown in figure 31. One drains the front engine sump (*G*), through the screen (*H*). The other drains the oil from the rear sump (*G′*) and forces it back into the external supply for recirculation.

The oil breather (*J*) is usually located at the front of the engine and extends into the crankcase to prevent loss of oil through the breather at various attitudes of engine operation. Several baffles may be put in the breather to prevent the escape of oil mist under all operating conditions.

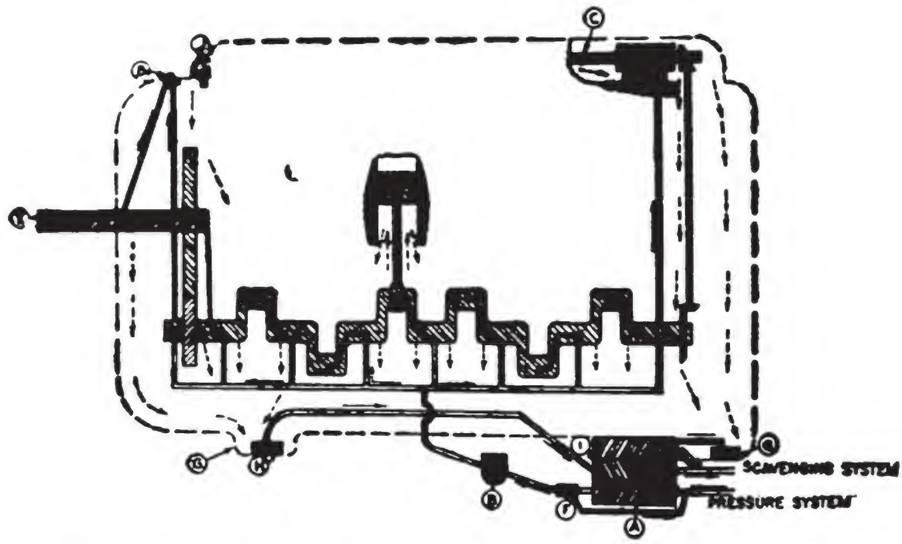


Figure 31.—Typical in-line or V-type engine lubricating system.

RADIAL ENGINE LUBRICATION

The semi-diagrammatic drawing shown in figure 32 discloses the arrangement of the internal oil system in a modern radial engine of fairly simple construction.

If you will examine this diagram, you will see that the oil comes from the tank, usually through a coarse-meshed finger strainer. It is drawn by the pressure pump *P*, which is usually a GEAR PUMP driven by the crankshaft. The oil is discharged from the pressure pump into a passage which leads into the hollow crankshaft *C*. It is usually introduced into the engine at the rear bearing.

This bearing is provided with an ANNULUS, or groove, entirely around the interior of the bearing.

At the point where this groove surrounds the crankshaft, holes are drilled from the outside of the crankshaft into its hollow interior. The annulus is, of course, kept continuously full of oil by the pump. Since this oil is under pressure, it is forced through the holes drilled in the crankshaft into the interior of the shaft.

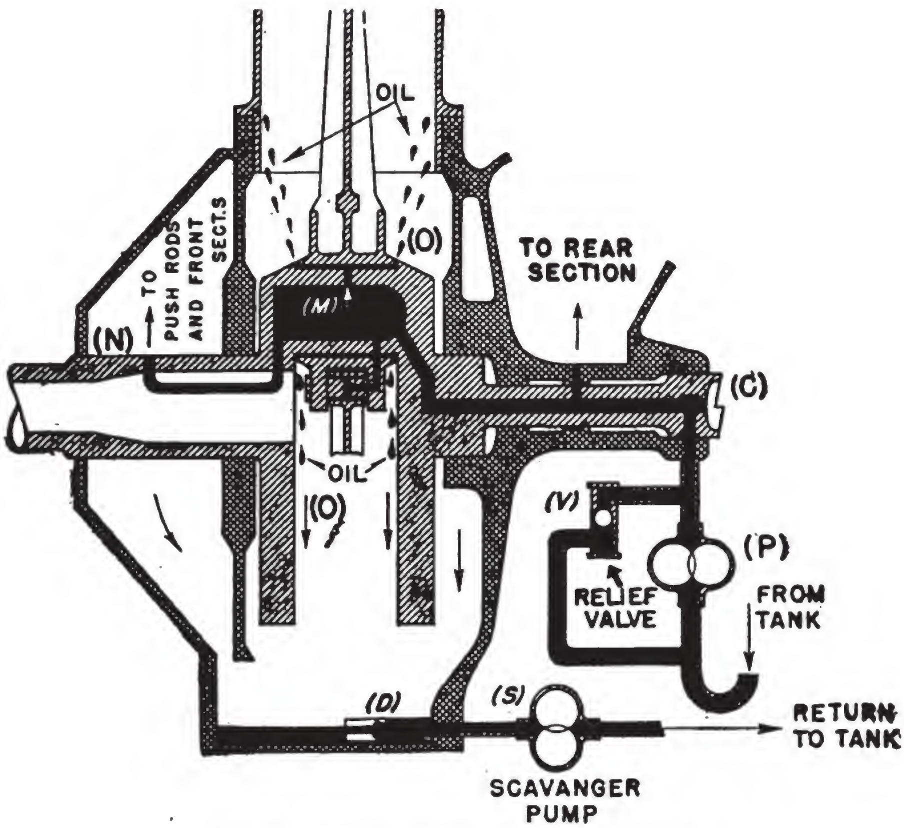


Figure 32.—Oil system of radial engine.

Other passages may lead from this annulus to the various accessory drives, supercharger gearing, and other points that require pressure lubrication. The oil can escape from the crankshaft only by oozing out between the bearing surfaces. The pump, however, is capable of building up an extremely high pressure and also of supplying a great deal more oil than the engine needs. If too much oil is supplied, the excess will work up into

the combustion chamber and foul the spark plugs, as well as produce an undue amount of carbon on the cylinder heads and pistons. Accordingly, the pressure of the oil must be maintained at a definite figure.

This pressure is determined by the relief valve, *V* in figure 32, which is simply a spring-loaded ball or plate, as you see in figure 33. The valve may be adjusted by increasing or decreasing the compression on the spring. In normal operation this valve remains partly open most of the time but only while the pressure is at the figure de-

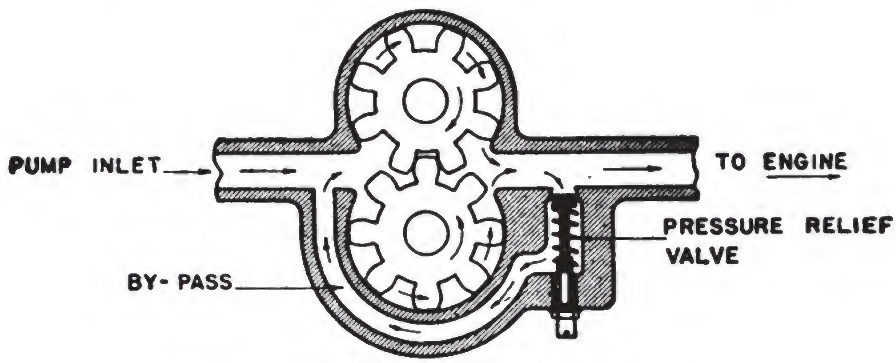


Figure 33.—Oil pump and relief valve.

sired. On the other hand, a small piece of foreign matter under the valve will hold it open and prevent the pump from ever building up the required pressure. Accordingly, if the oil pressure suddenly drops, one of the first places you should look is the pressure-relief valve.

The main connecting-rod bearing is lubricated by means of holes drilled from the outside of the crankpin to the interior, as shown at *M* in figure 32. The oil is forced through these holes and between the bearing surfaces. It is thrown off in fine drops, or spray, by the rapidly rotating crankshaft as indicated at *O*. Other holes through the crankpin line up with holes in the master rod bearing which lead through the knuckle pins.

Thus these pins are provided with fresh lubrication, and the excess oil that works out around the knuckle pin bearings is also thrown on the cylinder wall. This process lubricates the pistons, the cylinders, and all their moving parts.

From the crankpin a passage leads to the forward portion of the crankshaft, as indicated at *N* in figure 32. Oil from this passage is used to lubricate moving parts in the nose section, and by means of an annulus in one of the front bearings, may be led to the rocker arms and to the propeller governor control. OF COURSE, this oil is used ONLY if a hydraulically operated propeller is installed.

The oil that has been thrown on the cylinder walls is forced out of the bearings in the nose section and runs down the walls of the crankcase or falls, as indicated by the arrows, and eventually collects in the sump. Here it passes through a sump strainer, *D,* and is picked up by the scavenger pump, *S,* which returns it to the tank. This returned oil cannot accumulate in the lower cylinders, since the skirts of the cylinders project for an appreciable distance into and past the interior surface of the crankcase.

If the oil tank is very much above the bottom of the engine crankcase, the oil may sometimes leak past the pump into the engine and thus fill up the lower cylinders. The oil check valve should prevent this happening; but if it should occur and the engine were started with the starter, the cylinder heads would be blown off or some of the link rods might be bent. That's the reason all manufacturers recommend—before any attempt is made to start a cold engine it should **BE TURNED OVER SEVERAL TIMES BY HAND.**

OIL DILUTION

The difficulty in starting an aircraft engine in cold weather results from the high cranking torque (resistance to turning) of a cold engine. This resistance is caused by the viscous, sticky drag of the oil, particularly between the pistons and cylinder walls. You can see why thinning the oil before the engine is stopped in cold weather will greatly reduce the cranking torque and facilitate the next starting.

A system of oil dilution has consequently been developed in order to thin out the oil before stopping an engine, thereby speeding up cold-weather starting. In such a system a line connects the fuel pressure line to a special Y drain cock in which a spring poppet valve is installed. The valve is operated manually from the cockpit. Before the engine is stopped in cold weather, a small amount of fuel is allowed to enter the oil inlet line by holding the dilution control open for a short time with the engine operating. The diluted oil then replaces the heavy oil throughout the entire engine, thereby making the engine easier to start in cold weather. Make a note of this fact—YOU SHOULD NEVER DILUTE BEFORE STARTING A COLD ENGINE HAVING UNDILUTED OIL. IT WILL NOT HELP STARTING AND MAY CAUSE TROUBLE.

Inasmuch as some of the diluted oil is returned to a hopper in the supply tank during the last minutes of operation, this diluted oil will be the first oil used at the next start. This insures a more positive flow to the engine pump. A typical hopper installation is shown in figure 34.

Use of the oil-dilution system, as you would expect, increases the combustible vapor in the discharge from the engine crankcase breather. Consequently, a pipe is installed to conduct these vapors from the breather to the cowl line.

When the engine is at rest, there is also a tendency for the diluted oil from the tank to seep into the engine crankcase and into the cylinders. The problem created by this seepage has been solved by use of a check-valve installation in the strainer assembly in the engine. This valve is spring-loaded so that the normal gravity pressure of the oil cannot cause seepage into the engine. It opens readily, however, under the influence of

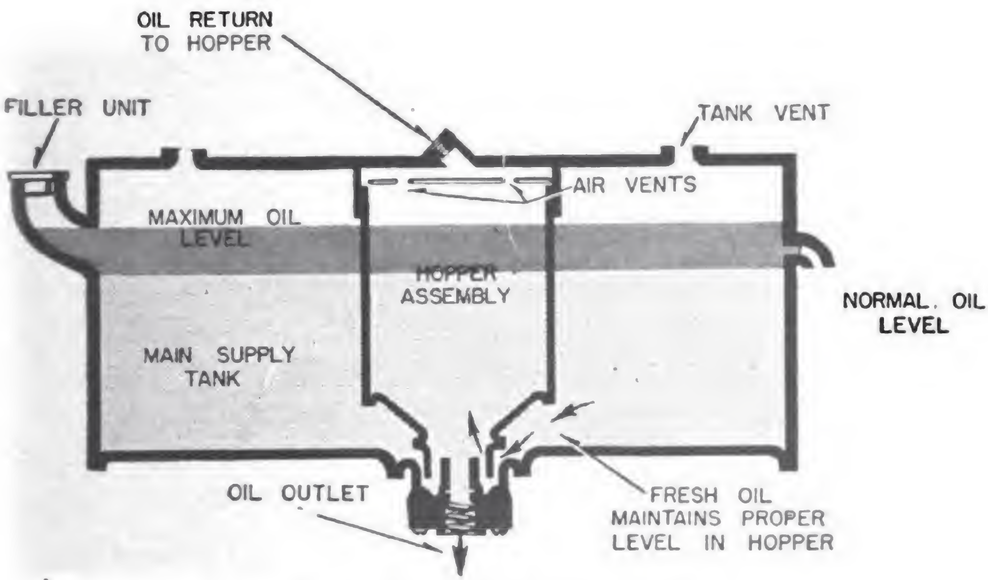


Figure 34.—Typical hopper tank.

pump pressure when the engine is in operation. Specific instructions for oil dilution are contained in the Pilot's Handbook for the airplane in which the engine is installed. You'll also find a Technical Order on the subject.

COLD WEATHER STARTING

In cold weather you'll have to heat the oil in an engine before you can start it. Usually if the air temperature is below 40° F., you will find heating of the oil not only recommended but neces-

sary. If the oil has been drained, you can heat it by placing it on a stove or by any other satisfactory method used at your base. If the oil is in the tanks, it will be too cold to drain, and you must use an electric immersion heater. This is a warming device, operated electrically from the outside, by which you can quickly raise the temperature of the oil in the tanks to the desired point. Specially designed gasoline fired heaters are now recommended for servicing large carrier-based aircraft in cold climates. After the oil has been heated, and before you prime an engine, you should turn it over 15 to 20 revolutions with the switch off, so as to start the warm oil flowing through the interior.

If the temperature is lower than 10° F., you will find it best to heat the entire engine by means of a canvas heater. This device consists of a cover which encloses the engine. At the bottom there is a large tube of fabric leading downward and enclosing a small stove. You should light the oil stove half an hour or more before the engine is to be started. The canvas hood keeps the heat enclosed around the engine, so that all parts are warmed. Remember, though, that this heating arrangement is used in addition to the heating of the oil.

CHAPTER 6

THE COOLING SYSTEM

AIR vs. LIQUID

If you were once your own jalopy's doctor, you probably know something about engine cooling—or heating. Remember how the old radiator sometimes boiled over and belched steam?

If you have been through such trials, you don't need to be told that gasoline engines generate terrific heat in their cylinders, sometimes as high as 4,000° or 4,500° F. Such temperatures are almost twice those necessary to melt iron. You can visualize the distorted, molten mass your engine would become, if cooling were not provided.

You've learned that the power developed by an engine is directly proportional to the heat of combustion. Yet it is essential that the operating temperature of an engine be maintained within safe limits to prevent warped valves, failure of spark-plugs, and other disadavantages of a hot engine. Cooling, of course, results in energy loss, generally about 30 percent of the total energy generated. This loss, however, cannot be reduced

to any extent without decreasing the reliability of engine operation.

Obviously, therefore, aircraft engines, powered by hi-test gasoline and operating at great speeds, must have adequate and dependable cooling systems. Some aircraft engines are air-cooled. Others are liquid-cooled. Both methods have definite advantages.

The AIR-COOLED ENGINE IS USUALLY LIGHTER IN PROPORTION TO ITS HORSEPOWER since it has no jackets, liquid, or radiators. It takes up less space lengthwise. The simplicity of the system makes it practically free of cooling failures, and the individual cylinder arrangement makes it more easily accessible to repair. It is also less vulnerable to gunfire in military aircraft. This, you will agree, is a good point these days.

The LIQUID-COOLED ENGINE generally has a smaller frontal area that lends itself to BETTER STREAMLINING in the nose. This permits greater speed and gives the pilot increased visibility. Such a system also has a better temperature control and makes possible more definite temperature readings, so that the cooling of the entire engine may be quickly analyzed.

AIR COOLING

The principle of air cooling is as simple as blowing on your soup to cool it off. When cool air from the propeller stream of a plane comes in contact with hot metal cylinders, the heat is dissipated. The greater the surface exposed, the quicker the cooling process works. Likewise, the faster the cool air is blown against the surface, the more effective is the air cooling.

More formally, the principles of air-cooling might be stated as follows—

The rate of air-cooling in an aircraft engine is directly proportioned to the area of the surface exposed to the cooling medium. The rate is further dependent upon the thermal (heat) conductivity of the metal used, the volume of metal or cross section surface, the mass flow of air over the heated surface, and the temperature of the cooling air.

As you already know, air-cooled cylinders are made up of steel barrels and light alloy heads

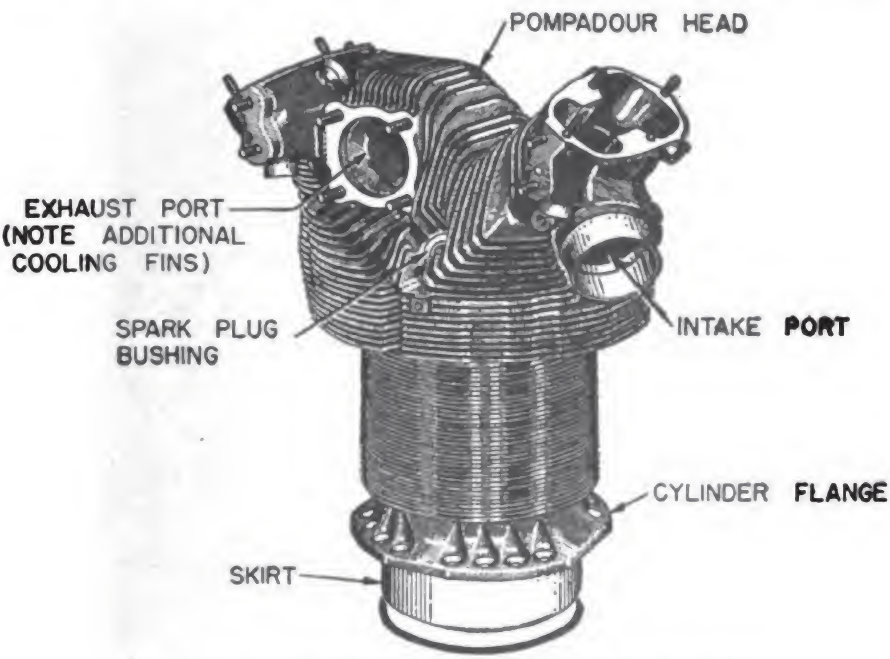


Figure 35.—Fin arrangement on air-cooled cylinders.

heavily finned for strength and for adequate cooling. Take a look at figure 35 to see the fin arrangement on an aircooled cylinder. Exposed fin areas have been increased from approximately 600 square inches on the old type of cylinder to 2,800 square inches on the new type cylinder. This increase in surface area takes care of the extremely high combustion temperatures obtained with the use of improved fuels.

Air deflectors or pressure baffles are installed

in high-performance aircraft engines to use the cooling air more effectively. Figure 36 shows a typical pressure baffle system for a twin-row engine. As you see, the baffles guide the air flow and increase its velocity over the cooling fins. Pressure baffles, however, may result in inadequate cooling during ground operation, when the air flow is of lower velocity. Overheating might then occur. That's why GROUND OPERATION OF AN ENGINE MUST BE RESTRICTED TO A MINIMUM BEFORE TAKE-OFF AND FLIGHT. Right here, you'd better

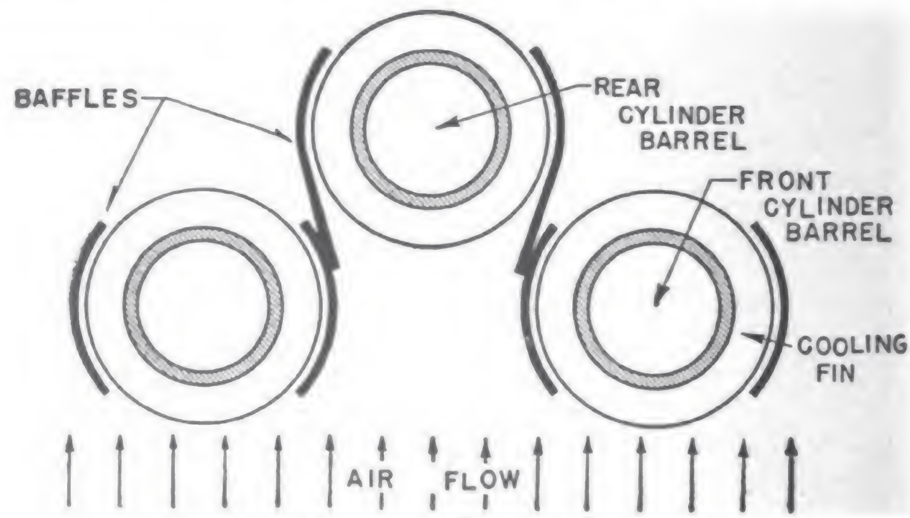


Figure 36.—Pressure baffles for twin-row engine.

make a mental note of the fact that cowl flaps should always be fully OPEN during ground operations.

Streamlined full depth NACA cowling* around the outside circumference of the cylinders also improves cooling efficiency. Such a cowling consists of a hood, or ring, and a portion of the body behind the engine. The cooling efficiency will vary with the speed of the aircraft or velocity of the air flow. As a general rule, however, cooling designed for efficiency at high air velocities is somewhat inefficient at low air velocities, parti-

**National Advisory Committee for Aeronautics cowling.*

cularly when the engine is being operated on the ground. To overcome this difficulty, controllable flaps may be placed in the trailing edge of the NACA cowling, as in figure 37.

Some air-cooled engine installations in low-performance airplanes have a cowling over the front crankcase section. This provides a means of control by which the airflow can be circulated

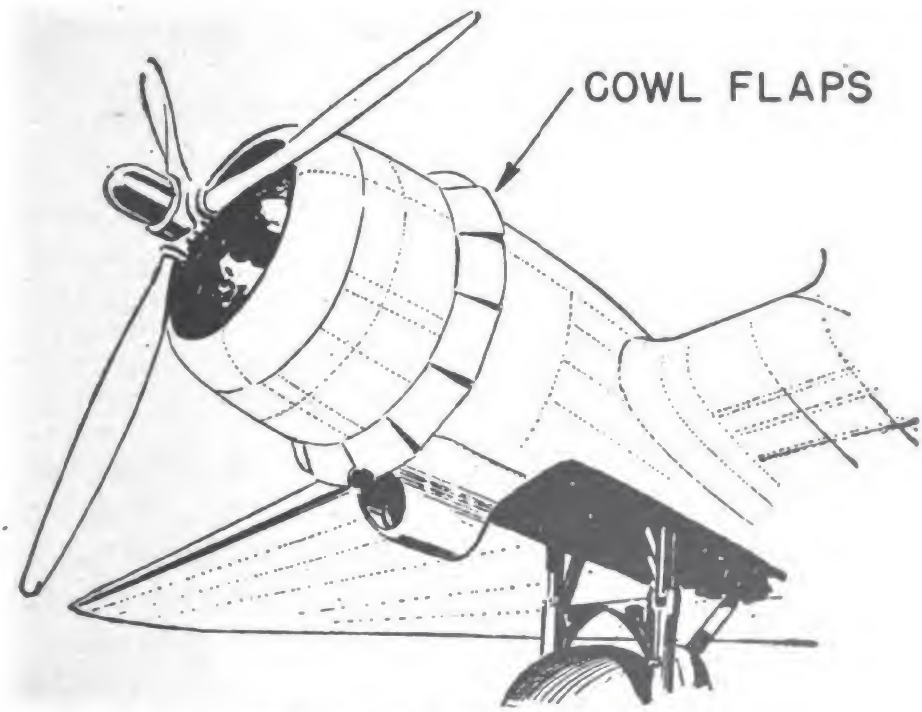


Figure 37.—Cowl flaps and NACA cowling.

around the crankcase in warm weather, and partially closed off in cold weather.

The cylinder head temperature is measured with a THERMOCOUPLE mounted at the spark plug, as illustrated in figure 38. This device measures temperatures by the electric current generated in a "couple," made by joining two different metals. When one metal is kept at a constant temperature and the exposed portion of the other metal is subjected to a change in temperature, an electromotive force is produced. The changes in this

force are measured on a dial calibrated in degrees.

This type of thermocouple is usually installed in place of the standard spark-plug gasket in the particular cylinder which proves by test to be the hottest under most operating conditions. Where an attachable spark-plug shield is used, the thermocouple gasket is installed between the

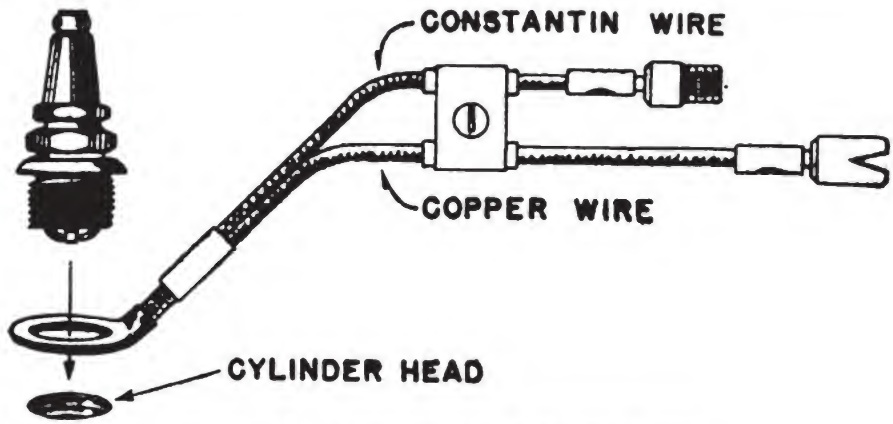


Figure 38.—Spark plug type thermocouple.

shield and cylinder head. The two thermocouple wires are of copper and iron constantin, each wire properly designated for correct installation on the cylinder temperature indicator in the aircraft cockpit. Cylinder base temperatures may also be measured with a thermocouple, the two wires being imbedded in the cylinder barrel flange and connected to the indicator in the same manner. You should consult operating instructions for specific temperature limits for various engines.

LIQUID COOLING

You've already found out that the Navy uses very few liquid-cooled engines. But, you should have a general understanding of liquid-cooling anyway. The cooling system of an air-cooled engine is, for the most part, self-contained. The liquid-cooled engine, on the other hand, has sev-

eral auxiliary units, including the radiator, auxiliary expansion tank, and the necessary plumbing connections. There are also a thermometer and gage indicating the operating temperature of the coolant (cooling fluid), a controllable radiator shutter assembly, and one or more centrifuge tanks.

The job of the radiator is to keep the temperature of the coolant within safe limits. Head resistance is an important consideration and is much less for a liquid-cooled engine than for the ordinary air-cooled engine. The core of the radiator is usually constructed of copper, and the tanks or headers of brass. The cartridge core type of radiator, which you see in figure 39 is a

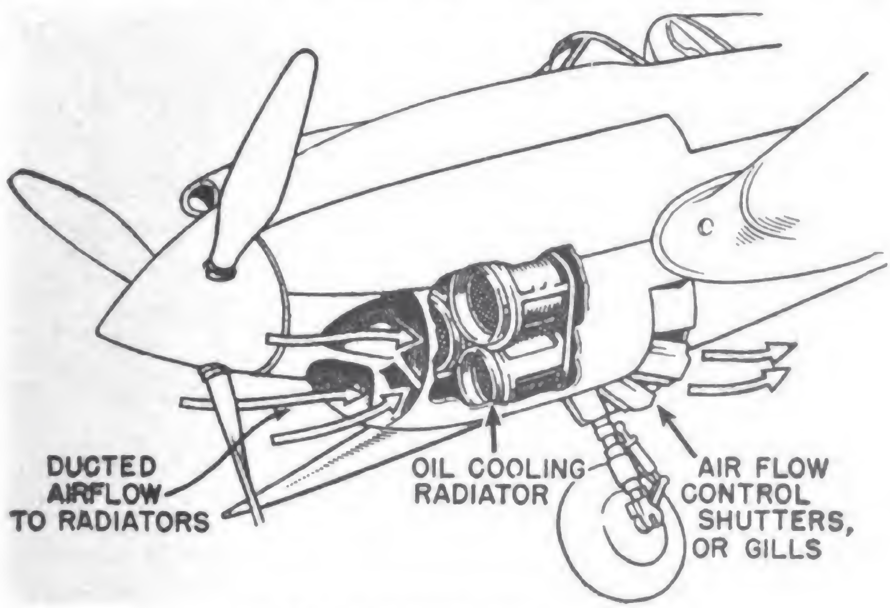


Figure 39.—Cartridge core type radiator.

conventional type usually strapped on or mounted in cradles. A shutter assembly may be installed on the exit side of the radiator and may be controlled by hand from the cockpit, or automatically through a temperature-operated control assembly. When the two are combined, the automatic feature functions as a safety device and opens the

shutters if the coolant reaches a predetermined temperature.

The auxiliary expansion tank provides an expansion space for the coolant in the system, as it becomes heated. It is installed at the highest point in the system and serves as the filler unit through which the entire system is serviced with coolant.

In the operation of water-cooled power plants, WATER TEMPERATURE SHOULD NOT EXCEED 85° C. Where ethylene glycol, or Prestone, is utilized as a coolant its temperature MUST NOT EXCEED 150° C.

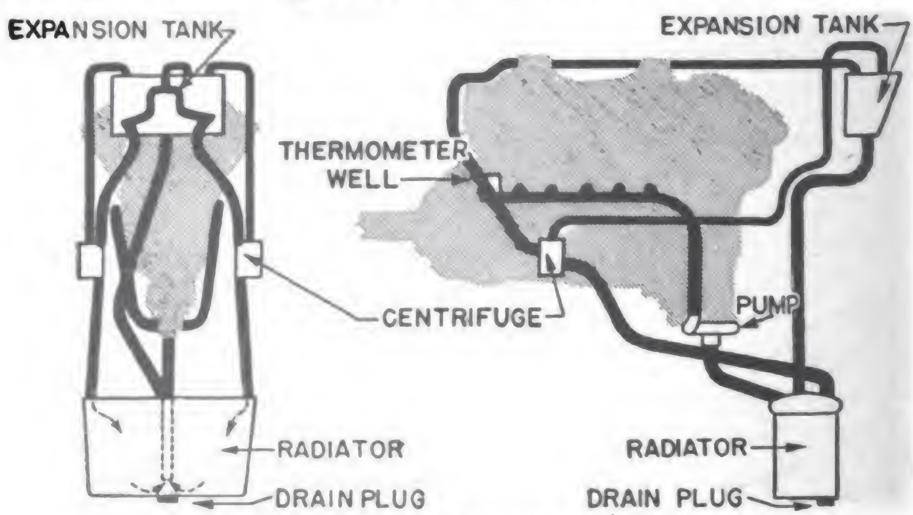


Figure 40.—Liquid cooling system.

With an adequate supply of coolant and proper functioning of the system, excessive temperatures may be prevented by using the shutter control. In case no shutter control is installed, high coolant temperatures may be reduced by retarding the throttle or by enriching the mixture with the mixture-control.

Now if you will examine figure 40 you'll see the arrangement of a typical liquid-cooling system. This diagram discloses how the various units operate together to cool high-powered engines generating terrifically high temperatures during combustion in the cylinders.

A large number of liquids may be used as coolants for internal-combustion engines, but only water and ethylene glycol meet the requirements of liquid-cooled aircraft engines.

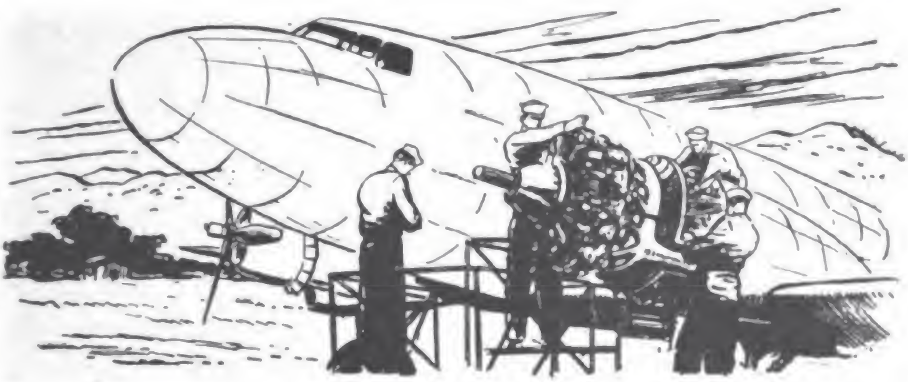
As you know, water is used widely as an engine coolant. That's because it is READILY AVAILABLE and is a MORE EFFECTIVE COOLING AGENT than any other liquid. But after your experiences with your old jalopy or your snappy roadster—if you were that lucky—you're well aware of the disadvantages of water compared to ethylene glycol (Prestone). You know that water has a high rate of evaporation and a LOW BOILING POINT. If water is the coolant, you have to give the radiator a drink often. Then, too, water has a HIGH FREEZING POINT which means trouble in cold weather or at high altitudes. Moreover, when it freezes, it expands, and, if this occurs, the entire cooling system will probably be damaged.

The comparatively low boiling point of water, 100° C., necessitates the use of a large radiator and a large amount of water to maintain an operating temperature below 88° C. You can see that this results in a high head resistance and a high weight per horsepower in aircraft engines. Most of the water used in engine-cooling systems comes from wells, rivers, and lakes, and, even though filtered it is somewhat impure. Consequently, frequent draining and flushing of the system are necessary.

Ethylene glycol (Prestone) is a chemical substance. Ethylene is obtained from petroleum oil or by the destructive distillation of carbonaceous (containing carbon) matter. Prestone is an excellent liquid coolant, because it is soluble in any proportion and when mixed with water freezes in

the form of slush instead of a solid. Also the mixture freezes at lower temperatures than does water. This temperature depends on the ratio of Prestone to water.

Glycerin is used to some extent as an antifreeze in water-cooled engines but not in aircraft engine cooling systems. That's because of its "gumming" characteristics and the difficulties encountered in preventing it from leaking out of the system.



CHAPTER 7

ENGINE ACCESSORIES

HELPING IT WORK

A big and complicated engine, such as is used on a Corsair fighter, must have lots of little gadgets to help it do its job. These small helping units are called ACCESSORIES.

You'll find that many of them are mounted on the rear case of the engine. This case, usually constructed of magnesium alloy, has mounting pads for the accessories and houses the gear train for driving them. The gears, operating the various accessories, are driven by a drive shaft splined, or attached in some other way to the crankshaft.

Earlier in this book you learned how some of these helping units fit into the engine's operation. These include carburetors, primers, sparkplugs, wiring, shielded ignition harness, intercylinder baffles, oil coolers, air preheaters, relief and bypass valves and others.

But the rear section of the engine is usually thought of as the accessory section. Here you find such units as the tachometer drive (measuring rpm), starter drive, generator and control

boxes, hydraulic and vacuum pumps, gun synchronizer, and others, depending on the engine with which you're concerned. Figure 41 shows a view of an engine's accessory section.

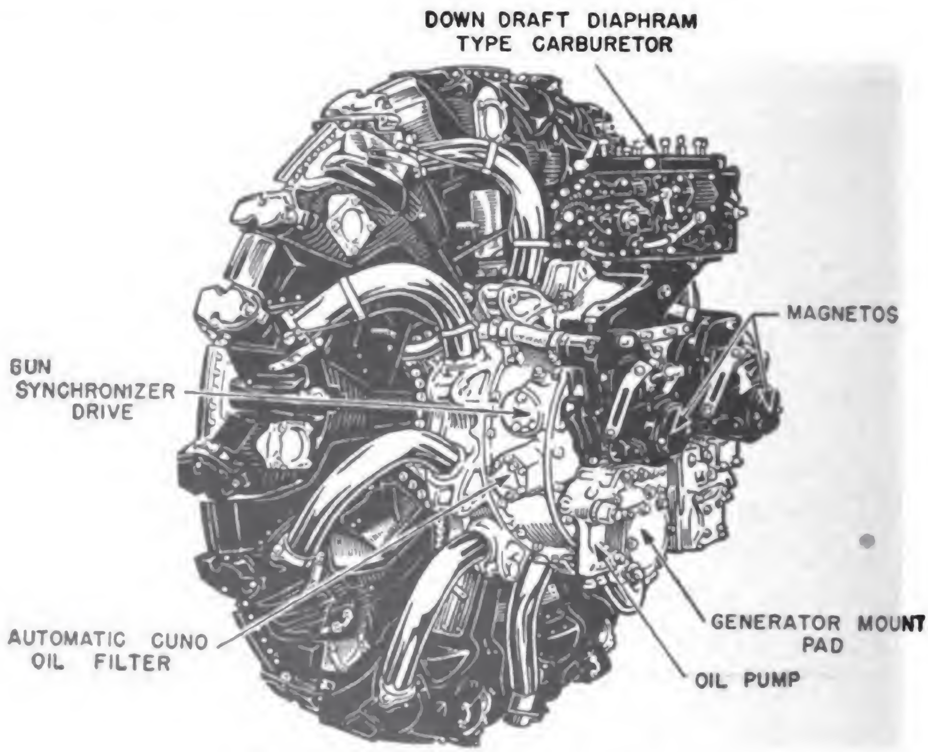


Figure 41.—Rear accessory section.

STARTERS

You'd hardly consider the propeller as a type of starter, but for many of the airplanes that you used to see, the only method for starting was by "pulling the propeller." It's the oldest method and the most dangerous as well. People have been killed by slipping on muddy or icy ground or as the result of pure carelessness while pulling the propeller. So be sure you're extremely careful and that you follow the prescribed rules whenever it's necessary for you to start an engine by pulling the propeller.

This method is used only on the smaller air-

planes today. As engines became larger and higher powered, a more suitable means of cranking them had to be devised. This was because of increased starting friction and the added complications of the power plants. Moreover, the propeller was often located at inconvenient positions for pulling through by hand.

The DIRECT CRANK is used on engines of less than 300 hp. You don't need to be told much about this method, as it consists simply of a crank geared directly to the crankshaft through reduction gears. It has a friction clutch that will prevent the handle from flying backward in case the engine backfires.

The CARTRIDGE STARTER uses a cartridge about the size of a shotgun shell, but loaded, of course, with powder only. Cases have been reported where pilots or mechanics who weren't "on the ball" attempted to use a Very pistol cartridge in the combustion starter. So make sure you are never careless in using this type of starter.

THE CARTRIDGE STARTER WORKS THIS WAY—

> The gas from the exploding cartridge is led through a tube to the starter mechanism. This mechanism consists of one cylinder with a piston working in it. As the piston is moved away from the cylinder head by the expanding gas it rotates a threaded shaft, which, in turn, rotates the crankshaft of the engine.

The HAND INERTIA STARTER depends for its operation upon the inertia built up in a rapidly revolving fly wheel. This wheel can be connected through a clutch to the engine crankshaft.

> The inertia built up by cranking imparts to the flywheel a tendency to continue revolving after the crank has been discharged. The

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gear ratio between the two is very high. This means the crank must be turned slowly at first, with gradually gathering speed. After the starter has reached its maximum speed, the crank is disengaged (by pulling it out) and the pilot is ready to start the engine.

The ELECTRIC INERTIA STARTER is like the hand inertia starters except that the starter is turned by an electric motor. Power for the motor is supplied from a storage battery.

The DIRECT ELECTRIC STARTER is one of the most widely used in aircraft and is like that used on an automobile. It consists of an electric motor, speed reduction gear, overload clutch, and automatic engagement dog (holding device).

Finally there's a RULE in connection with starters which you should ALWAYS OBSERVE. NEVER operate any type of combustion or electric starter without first shouting "CLEAR" and being assured that no one is in line with the propeller.

GENERATORS

The modern airplane has so many electrical accessories, such as starters, landing lights, retractable landing gear units, and radio, that even the smaller types of airplane are usually equipped with storage batteries. But these electrical devices would soon exhaust the batteries, unless they were kept charged while in flight. Consequently, a generator has to be mounted on the engine.

As you know, the engine in an airplane is running continuously at an rpm near its maximum. Thus, you see, the generator tends to maintain an extremely high output. But, if the airplane is operating during daylight, little current is drawn from the battery, and even at night the consumption is small, except when landing lights are used.

On the other hand, a large amount of current is needed for starting and for the operation of the landing gear and flaps through short periods of time. Consequently, the generator must be capable of very quickly recharging a practically exhausted battery.

The generator on an airplane engine is operated by a shaft driven by the main accessory drive shaft through a gear arrangement. A regulating mechanism takes care of the intermittent load requirements and at the same time prevents overcharge of the battery. This mechanism is contained in a separate control box. It automatically varies the output of the generator, depending on the state of the charge in the battery, and also varies the amount of current being drawn from the battery and the generator at that ime.

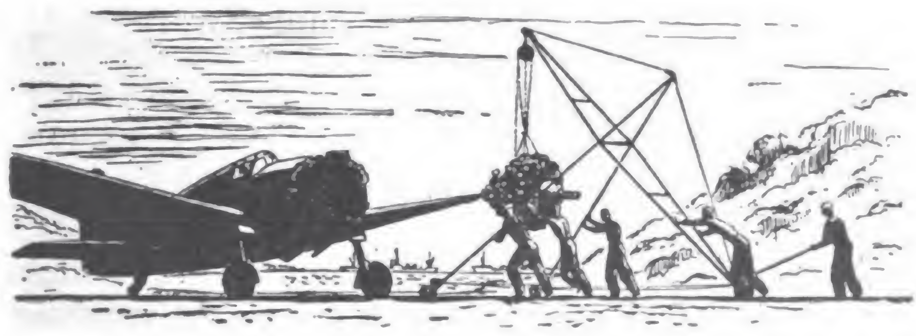
PUMPS AND GUN SYNCHRONIZER

Most FUEL PUMPS are mounted directly on the engine and are driven by a square, torque, or splined-drive coupling. The fuel pump drive is actuated by a shaft connected by a gear arrangement to the main accessory drive shaft. Uusually the shaft is driven at less than crankshaft speed and often in a counterclockwise direction. Before installing a pump, you should check the proper direction of rotation.

On Navy airplanes a whole slew of odd jobs are done by hydraulically actuated mechanisms. Bomb bay doors are opened and closed, landing gears retracted and extended, and wing flaps opened and closed. Hydraulic fluid must be pumped from a reservoir to the parts you want moved by hydraulic force. This job is done by a HYDRAULIC PUMP driven by the engine through an auxiliary drive shaft.

Have you ever wondered how it was possible to send bullets whizzing between the blades of a revolving propeller?

That's accomplished by a little gadget called an IMPULSE GENERATOR. It's used on all airplanes having machine guns mounted so as to fire through the rotating propeller blades. This gun SYNCHRONIZER is usually attached to the rear section of the engine and is driven by a rotating cam, geared to an accessory drive shaft rotating at propeller speed. The cam follower roller, riding up and over the cam lobe (or "bump"), actuates a trigger motor which fires the gun at just the right moment. And that moment HAS to be right—or else you have a shattered prop.



CHAPTER 8

OVERHAUL AND STORAGE

GOOD CARE PAYS

Navy airplanes face tough duty in wartime. In the pinches they have to "take it" and they do. In between times they deserve the best of care. It's up to you to give it to them.

During long hours of operation from Alaska to the South Seas, they're exposed to wide temperature changes. These may cause an expansion or contraction of parts. Sometimes a permanent SET or distortion results and reconditioning is necessary.

Sludge chambers and pockets in the engine become filled with sludge, carbon, lead deposit, and dirt.

Piston ring grooves and combustion chambers become "coked" or covered with carbon deposits. The deposits on the surface of the chamber interfere with heat conduction. Moreover, the skirts of pistons, bearings and other rubbing surfaces may become scratched or scored. This increases the friction.

These are just a few of the results of continued use of an engine. They add up to just one word in your language, and it's OVERHAUL.

Navy aircraft engines should be overhauled at regular intervals and oftener if necessary. Most manufacturers recommend a thorough 50-hour inspection and a general overhaul after about 350 to 400 hours of engine operation. But you should be guided by the condition of the engine and by Bureau of Aeronautics regulations in this regard. You'll find specific instructions for disassembly, inspection, repair and assembly in the manufacturer's overhaul manual.

"EMBALMING"

No, you're not in an undertaking establishment—even though the word "embalming" suggests unpleasant things. This book is still talking about engines. Embalming, as used here, refers to preservation precautions which must be taken when an engine is put in storage.

Do you know that an engine will deteriorate more rapidly when not in use than when in operation?

Corrosion does it. Unchecked, it will eat away vital engine parts. But if you take the proper precautions, you can treat an engine so that it will be none the worse after either short or long storage.

The Bureau of Aeronautics issues detailed instructions for corrosion-preventive procedure. Basically, it's accomplished in two steps. First, you treat the interior of the engine with a corrosion-preventive compound. It's done by adding the corrosion-preventive compound to an Army-Navy aeronautical specification lubricating oil. You introduce it into the engine during operation just before shut-down.

Second, you put the engine in a moisture-proof envelope. You have to dehydrate the air in the envelope, too. That means removing all the mois-

ture or water from the air. You can accomplish this dehydration by using SILICA-GEL. If you add a chemical, called cobalt chloride, to the silica-gel, a blue color results when the gel is dry. A pink color develops if moisture is absorbed.

The specific steps in the embalming process are not listed here. The brief summary that follows will give you a good general idea of the procedure. Remember, though, that you should follow the detailed instructions set down in Technical Orders and Notes when you approach such a job in actual practice.

INSTALLED ENGINES

When you know definitely that an airplane is grounded for more than 7 days but will be operated within 30 days, you should take special precautions to prevent corrosion even though the time may seem short.

In general, the process for an installed engine involves removing spark plugs and rocker box covers. Then you should spray exhaust valves, and cylinders with corrosion-preventive mixture. A dehydrating agent is placed in the exhaust outlets and in the carburetor intake scoop. After you've completed the various precautionary measures according to instructions, you should put a warning tag or plate in the cockpit. A similar tag should be attached to the propeller. These warnings should state that the engine must not be turned over nor operated until "depreserved" or "disembalmed."

STORED ENGINES

If an engine is to be removed from an airplane and won't be in use for 30 days or more, you'll have to take additional precautions to prevent

corrosion. Be sure to check the specific instructions, contained in Bureau of Aeronautics Technical Notes and Orders before you begin. First, at the end of the final run, you should circulate a mixture of three parts lubricating oil and one part preservative compound through the engine. You should also introduce an additional quantity of the oil preservative mixture through the impeller and into the intake manifold. This will cover the induction system and cylinder heads with the preservative compound. Drain the lubricating oil from the crankcase, filter or screen chambers, and sumps while the engine is still warm.

After this, carefully spray the various parts as directed with the specified compound-lubricating oil mixture. Empty the carburetor of all gasoline and fill it with the specified oil. Anchor a fresh dehydrating agent in the intake manifold and openings, and also in the carburetor intake—if that device is to be left attached to the engine. Seal other openings or install dehydrator plugs as directed. Finally, place the engine in a moistureproof envelope.

You should inspect a preserved engine at least monthly to make sure the humidity in the engine envelope is below 20 percent. The color of the dehydrating agent will serve as an indication of the relative humidity in the envelope. If the humidity is above 20 percent, you should represerve the engine.

"DISEMBALMING"

Your engine has been under wraps for 30 days. Now you're ready to put it back into service.

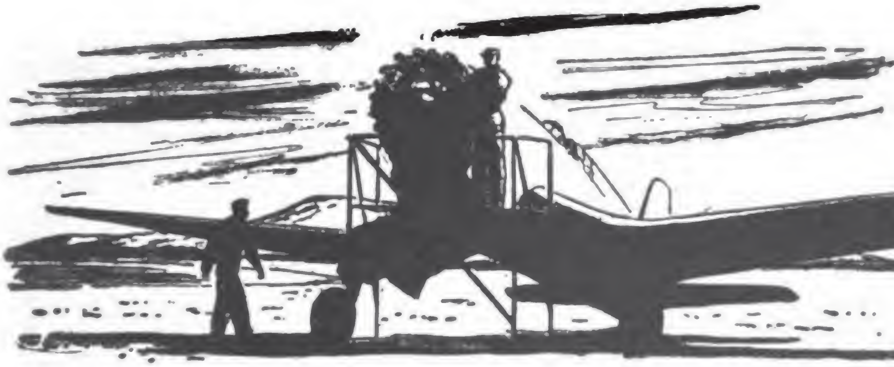
First, remove all plugs, cover plates, and wrappings. Rotate the crankshaft a few times to make sure the valve mechanism is working. A

mixture of gasoline and lubricating oil will loosen up mechanisms that stick. Remove any excessive corrosion preventive from the cylinders by use of a hand pump. Install spark plugs and prepare engine for operation.

If, on the other hand, your engine has been tucked away in the old graveyard for several months, you've got a more complicated job ahead. First, you have to remove it from the envelope. BUT remember that these envelopes are made of strategic material. You can use them at least six times if you're careful. Next, you should remove all bags of dehydrating agent. In no case, however, should you drain the corrosion-preventative compound from the engine or propeller shaft sooner than a week before the INITIAL GROUND RUN-UP of the engine after installation.

When you're sure the engine is going to be in operation within a week, you can go ahead with the various "disembalming" steps. Remove all moistureproof coverings on breathers, exhaust manifold, and intake manifold. Remove dehydrating plugs, cover plates, and wrappings. Drain the corrosion-preventative mixture from the engine. Use a hand pump when necessary. Remove and clean the Cuno oil strainer with gasoline. Rotate the crankshaft a few times to make sure all excess compound has been removed from the engine. Slush the carburetor thoroughly to remove oil. Install the spark plugs and connect them to the ignition system. Put enough oil in the oil tank to insure satisfactory lubrication for a short period.

At this point you're ready for a ground run-up. Afterward, drain the oil from the engine and oil system. Then fill the oil system with new oil before running the engine further.



CHAPTER 9

TROUBLE SHOOTING

KEEP 'EM FLYING

When pilots are playing hide and seek with Japs, they can't afford to worry about the mechanical perfection of their engines. Those engines have to be right—or else! Battles and lives are at stake.

Your first responsibility is to keep the engines you work on in the best possible condition. You can do this by frequent inspections and by painstaking care. But the time is bound to come when the engine or some part will not function properly.

Will you be able to solve such an engine problem?

You'd better be able to solve it. It's your job as a TROUBLE SHOOTER to locate the difficulty and correct it. Whether or not you're successful depends upon your understanding of engine principles and engine "weak spots," and your ability to think clearly and logically. One way that you'll be able to locate engine troubles quickly and consistently, is by taking every opportunity to work with an experienced trouble shooter. You can learn a lot by observation and

by developing the habit of anticipating engine troubles.

For instance, when you're working on a part, notice just how it's made and how it fits into the engine. Ask yourself what would happen if the part failed. Try to figure out what the logical indications (or symptoms) of such a failure would be, and, of course, what steps you should take to prevent the part failure.

There's no set procedure for locating engine troubles. First, though, you've got to analyze the problem correctly and specifically. Don't be content with any slipshod analysis. It's not enough to say the engine doesn't run properly. Instead, you should define the trouble exactly.

Suppose you engine doesn't fire the way it should. Your next step would be to find out which cylinder or cylinders are missing. You find that No. 6 isn't firing. You've narrowed down the scope of your problem. Now ask yourself the question—

WHY DOESN'T THE CYLINDER FIRE?

There might be several reasons. Don't overlook any of them. You might consult the manufacturer's manual. Generally the manual lists troubles peculiar to the particular engine. After you've reviewed all possible causes, you should decide upon the one that seems most likely. Then investigate.

In the present example, it would be logical to suppose that the spark plugs are defective. It's worth a try anyhow, so remove the old plugs and put in new ones. Then test to see if the trouble is corrected. If not, you've at least eliminated one possible source of trouble and can continue further the process of elimination until you've found the trouble and corrected it.

Some of the more common engine troubles are

listed in the following pages. The list is in no sense complete, but it will serve as a general guide for you. In some of the cases, you'll need direction from an experienced man before you attempt to eliminate the difficulty. In others, the correction is obvious.

Failure Of Engine To Start—

Ignition switch off.
Out of fuel.
Oily or fouled spark plugs.
Magneto points stuck open or held apart.
Wax on magneto points.
Magneto ground wires broken and grounded.
Over or under primed.
Engine too cold.
Water in the carburetor.
Wet ignition (spark plugs, magneto, harness).
Failure of carburetor control to function properly.
Incorrect throttle setting.
Incorrect timing or valve clearance.
Air leaks in induction system.

Failure of Engine To Run Properly at Idling Speed—

Idling jet restricted.
Incorrect idling speed adjustment.
Throttle valve closing too far.
Cracked intake manifold.
Air leak in the induction system.
Improper valve clearance.
Engine fouls spark plugs when idling.
Excessive play in carburetor controls.

Failure of Engine To Develop Full Power—

You'll find that the rated power of an engine will vary under different atmospheric conditions or propeller pitch settings. Consequently,

you shouldn't decide that an engine is low in power, unless the drop in power is excessive under similar conditions. You should take these possible variations into consideration before looking elsewhere for the cause of the trouble, but here are some of the possible difficulties.

Faulty ignition—

Ignition out of time.
Weak magneto magnets.
Excessively burned or pitted points.
Defective spark plugs.

Incorrect carburetion—

Mixture too lean or too rich.
Throttle valve not fully open.
Improper grade of fuel.
Intake manifold too cold.
Air leak in carburetor.
Incorrect fuel pressure.
Turbulent flow of air in intake horn.

Improper lubrication—

Oil too heavy.
Oil temperature too low or too high.
Overhead not properly lubricated.

Miscellaneous—

Pre-ignition.
Incorrect valve timing.
Weak springs (valve action slow).
Improper valve clearance.
Compression too low.
Excessive carbon.
Leaking valves.
Exhaust manifold constricted (back pressure).
Engine stiff or tight.
Incorrect propeller setting.

Engine Stops—

Magnetos grounded.
Out of fuel.
Carburetor jets restricted.
Air or vapor lock in fuel line.
Fuel lines partially obstructed.
Structural failure.

Engine Misses Regularly on One or More Cylinders—

Fouled spark plug.
Defective spark plug.
Broken or grounded spark plug wire.
Improper valve clearance.
Low compression on one or more cylinders.
Damaged distributor head.

Engine Misses Intermittently—

Incorrect mixture.
Improper grade of fuel.
Water in fuel.
Air leaks in induction system.
Slow valve action.
Defective magnetos.
Distributor points or contacts dirty.

Improper Acceleration—

Improper idling adjustment.
Defective accelerating pump.

Improper Fuel Pressure—

Air leak in system.
Improperly adjusted relief valve.
Clogged strainers.
Vapor lock.
Leaky float.
Damaged needle valve.
Excessive fuel supply pressure.
Improper float level.
Worn fulcrum pin.

Improper Oil Pressure—

Air leak in system.
Improperly adjusted relief valve.
Clogged strainers.
Improper grade of oil.
Vapor lock.
Excessive bearing clearance.
Oil too hot.
Atmospheric temperature too low.
Lack of priming.
Oil foaming in supply tank.

Engine Vibrates Excessively—

Propeller out of balance or out of track.
Bent crankshaft.
Unequal valve clearance.
Defective spark plugs.
Engine loose on mount.
Propeller hub nut loose.
Improper hot air distribution.
Ice formation in carburetor.
Incorrect carburetor setting.
Engine too cold.

Excessive Fuel Consumption—

Mixture too rich.
Jets too large.
Ignition timing late.
Engine running too cold.
Worn piston rings.
Leaking valves.

Excessive Oil Consumption—

Improper grade of oil.
Worn piston rings.
Worn main bearing.
Crankcase compression.
Overheating.

Engine Won't Stop When Switch Is Turned Off—

Magneto ground wires broken.
Engine excessively hot.
Excessive carbon.

Oil Temperature Too High—

Improper grade of oil.
Oil that has been run too long.
Insufficient oil coolers.
Ignition too late.
Pre-ignition.
Improper engine cooling.
Improper grade of fuel.
Not enough oil.
Dirty oil.
Scavenger oil pump not cleaning crankcase.
Worn piston rings.
Piston rings installed upside down.
Improper venting.
Incorrect air baffling.

CANNIBALIZING

Some day you may be stationed at a base outside of the United States. If so, you're not always going to be able to get a needed part when you want it. But if you're smart and know your engines, you may be able to take the parts from an airplane that is disabled and put another in shape.

For instance, on the night of 12 October 1942, when the Japs gave Guadalcanal one of its heaviest Naval shellings, 15 Grumman Avenger Torpedo bombers were put out of commission. Sleepless ground crews vowed, however, that they could put 8 of these hard-hitting planes back into commission—IF THEY ONLY HAD SOME SPARE PARTS. There were no spares, but, by cannibalizing every

available plane for usable parts and by devising lash-ups that would have left an aircraft engineer speechless, these men somehow repaired 2 of the airplanes in 48 hours. Sad to say, the Japs subsequently blasted to bits the other 6 repairable planes as they stood, immovable and defenseless near the field.

So remember the possibilities of cannibalizing, if you're in a tight situation. OTHERWISE, you'd better think THREE TIMES before you butcher one airplane to fix up another.

YOUR ENGINE BIBLES

As you work on engines, you're going to have all kinds of questions come up about their construction and operation. When you're faced with a new engine, you'll want to learn a lot about it and in a hurry.

WHERE are you going to get such information and the answers to your questions?

There are some important sources of information on engines with which you should be thoroughly familiar as you approach your job. First, manufacturers of aircraft engines have in the past published an OPERATOR'S HANDBOOK for each of their engines. These handbooks, however, are now being prepared in a standardized form. The title of such books is now HANDBOOK OF SERVICE INSTRUCTIONS.

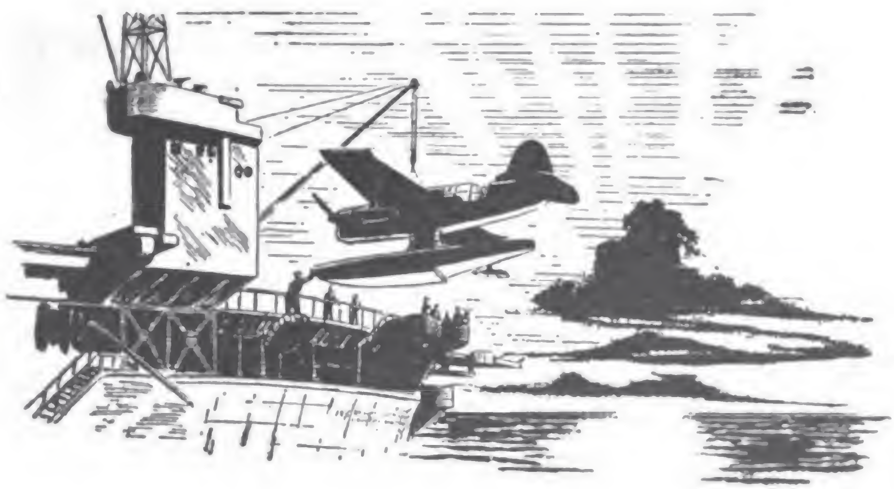
Both the old and the new type of book contain a description of the engine and information relative to its installation, servicing, and minor adjustments. If you're curious about how the lubrication system of a Twin Wasp R–1830–92 works, you'll find the answer in the old type OPERATOR'S HANDBOOK. If you want to know how to remove rust from a spark plug shell, the answer is in the handbook. There are hundreds of other details

regarding engines in these books, so you'd better make it a point to go through the ones on the engines you're servicing.

Then, of course, there's the indispensable OVERHAUL MANUAL, which is prepared by the manufacturers of various engines. This, too, is now being printed in a standard form. These manuals contain detailed instructions regarding dismounting, and disassembly of all engine parts, cleaning, inspection, repair, and replacement of engine parts, and reassembly.

There are various other materials with which you should be familiar. These include ERECTION AND MAINTENANCE INSTRUCTIONS and the service data supplied by the manufacturers of Naval aircraft and equipment. The PILOT'S HANDBOOK on different airplanes explains starting procedure and operating instructions. STRIP FILMS, put out by the Navy Department, show in detail many of the operations that you'll be required to perform on engines. These rolls of strip films will be available to you in most squadrons.

Other Bureau of Aeronautics publications with which you should be familiar are TECHNICAL ORDERS, TECHNICAL NOTES, AIRPLANE BULLETINS AND CHANGES, and ENGINE BULLETINS AND CHANGES. These provide current up-to-date information on modifications and recommendations for the care and servicing of aircraft engines and airplanes.



CHAPTER 10

RANGER–V–770

WHAT IT IS

One of the observation-scout airplanes in service is the Curtiss "Seagull" or SO3C–1 (or–2). You'll quickly recognize this monoplane by its upturned wingtips. It is designed for use either aboard battleships and cruisers as a catapulting seaplane or ashore as a landplane.

The "Seagull" is powered by the Ranger V–770 which is a 60° V, 12-cylinder, air-cooled, inverted engine. The supercharger is a single-stage single-speed blower. The propeller reduction ratio of the engine is 3:2. The horsepower rating at sea level is 450.

From your study of earlier chapters, you're aware of the advantages of this type of engine. It combines the light weight of the air-cooled engine, the small frontal area of an in-line engine and the good forward visibility made possible by the inverted position.

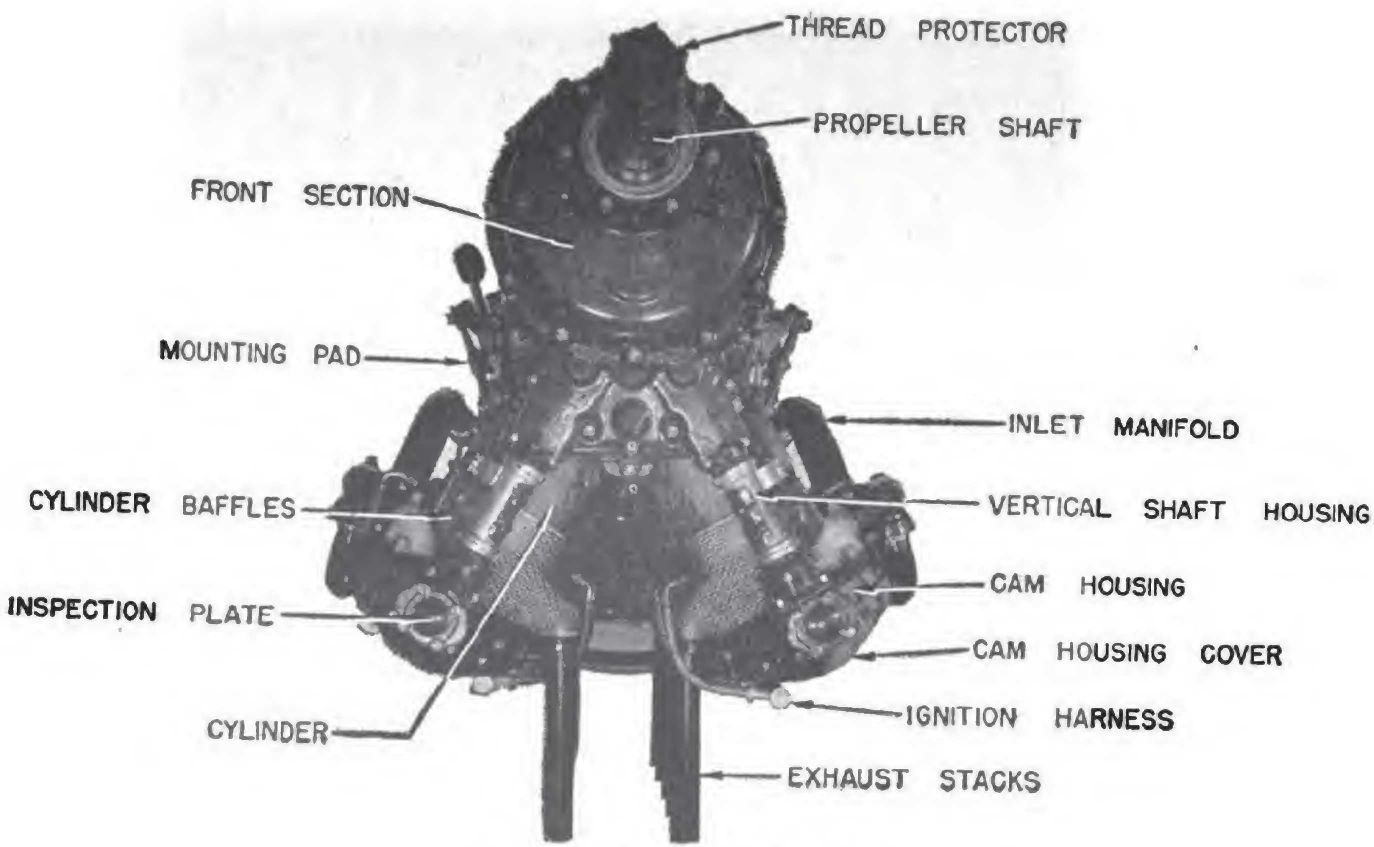
You can see that certain technical difficulties had to be solved to combine these various advan-

tages. The most serious was the cooling problem. As you know, only the front cylinders on a V in-line engine are exposed to a direct air blast. How could equal cooling be provided for all cylinders? The answer was PRESSURE COOLING.

The principle of pressure cooling is to provide an air chamber next to the cylinders, with its open end facing forward. The forward velocity of the airplane, as well as the fan action of the propeller, will build up air pressure in this chamber. Then, you see, the air pressure on one side of the cylinders is higher than that on the other side. Therefore, air will tend to escape around the cylinders and between the cooling fins. This assures a maximum cooling effect.

On the Ranger V–770 the pressure chamber is formed by an air scoop as shown in the first illustration. The bottom of the scoop is formed by a piece of sheet metal which fits tightly against the bottom of the camshaft housings. The sides of the scoop are formed by the cylinders. An end baffle across the rear of the scoop completes the pressure box.

The amount of cooling air flowing over the cylinders is governed by the difference between the high air pressure in the scoop and the much lower pressure within the rest of the engine cowling. You can see that the pressure in the scoop depends almost entirely on the forward speed of the airplane. The pressure on the other side of the cylinders can be varied by use of cowl flaps. In the full open position the passing air stream continuously removes the hot air from the cowling. This is necessary when the plane is standing still or moving slowly because the pressure in the air scoop is low. At high forward speeds there is enough pressure in the scoop to force the air through the fins, and the cowl flaps can therefore be closed.



Front view of Ranger V–770.

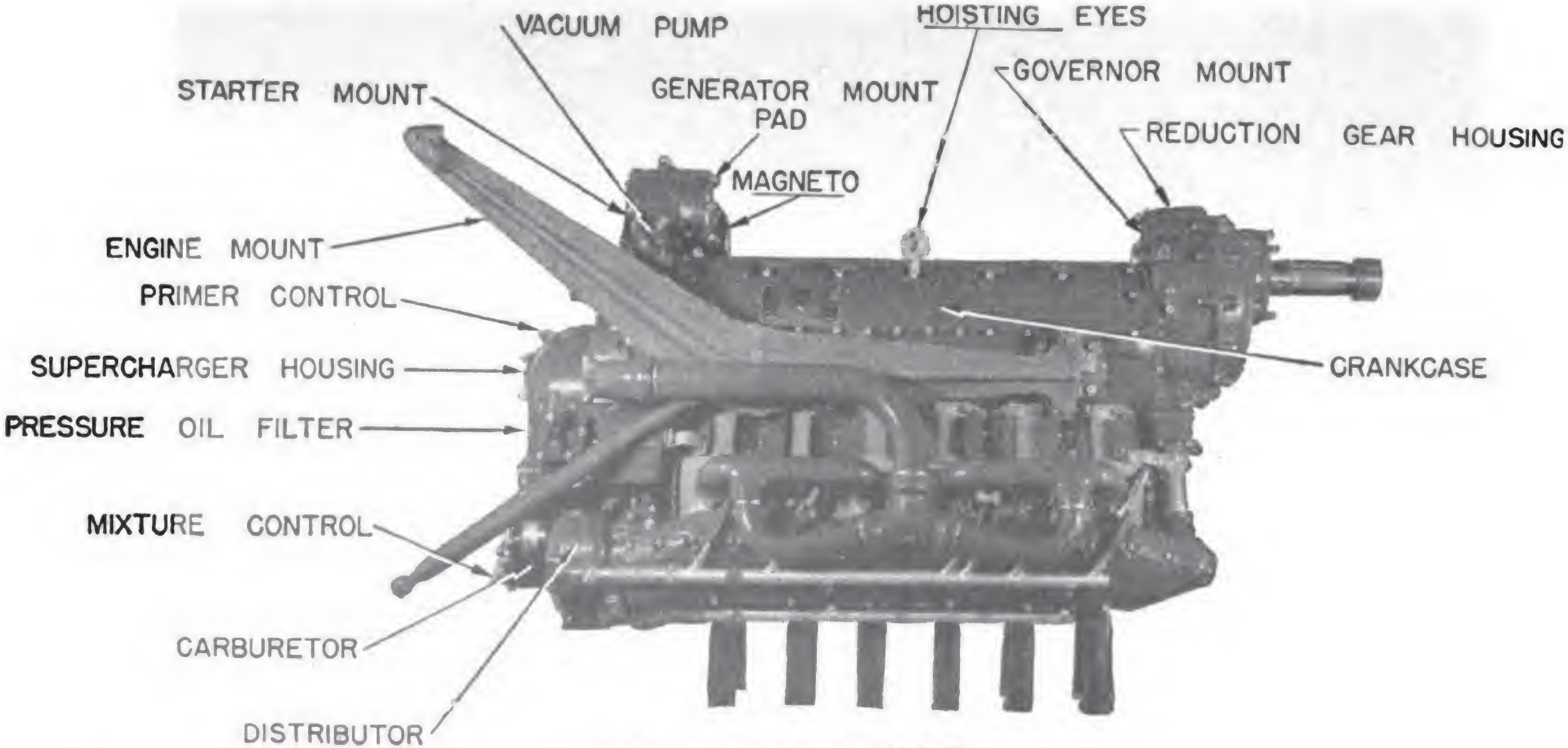
If you're working on this type of engine, be sure there are no leaks such as would be caused by loose baffles or by a poor fit between air scoop and engine. Otherwise, you're in for trouble, either overheating in the vicinity of the leak or possible damage to the engine. The entire system can operate effectively only if the air scoop and cylinder baffles fit tightly, so that the only path for air flow is through the cylinder fins.

ENGINE PARTS

Since this is an engine with in-line cylinder arrangement you'd expect a different type of crankshaft than that in the radials. On the V–770 it is a six throw shaft. The front end carries a gear tooth spline which engages the quill shaft. The rear end of the shaft carries a gear which engages with the starter and generator drive through an idler gear in the rear section. All other drives are taken off the propeller end of the shaft.

The crankshaft is equipped with dynamic vibration dampers. These dampers, as you know, are designed to absorb torsional crankshaft vibration when the engine is running. When the engine is turned over very slowly, you can hear these weights falling from one end of their track to the other as the particular crank throw moves across top center. When you hear this noise, you should recognize it as a normal sound and not get worried about the wrench you might have left in the crankcase.

The CONNECTING RODS are machined from alloy steel forgings. As the cylinders in the two banks are in line transversely, and the crankshaft has six throws, two opposed cylinders work on the same crankpin. Therefore, the connecting rods



Right view of a Ranger V-770.

are of the fork-and-blade type. The right rods are forked at the large end, while the left hand rods are of the narrow blade type and fit between the forks of the other rods.

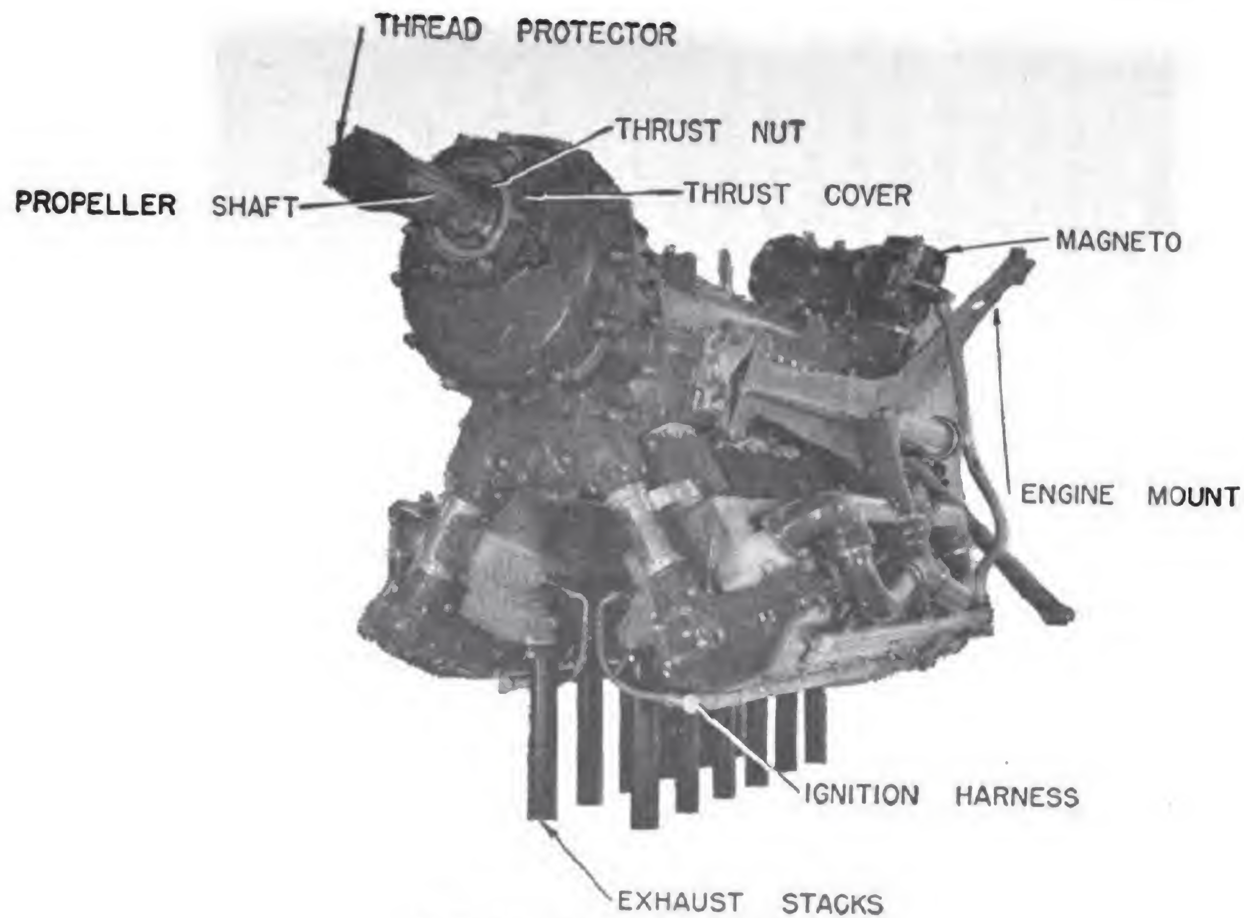
The PISTONS of forged aluminum alloy are of the full trunk type. Four piston rings are used. Three compression rings are located between the piston-pin boss and piston head. A beveled oil scraper ring is at the lower end of the skirt. Heat-treated alloy-steel piston pins are fully floating and are retained by spring circlips in the pistons.

The CYLINDER HEADS of aluminum alloy are cast with closely spaced fins. The barrels are machined from chrome molybdenum forgings and are screwed and shrunk into the cylinder head.

The FORGED STEEL CAMSHAFTS are carried in magnesium-alloy housings which bolt directly onto the cylinder heads. The camshafts are driven through bevel gears from a drive shaft at the front end and are supported in seven bearings. The valves are operated by steel rocker arms equipped with needle bearings. Cam followers are of the roller type. Tulip-type intake and exhaust valves are of forged alloy steel. The exhaust valve is sodium cooled. Both valves have two springs.

CARBURETOR

This engine is equipped with a Holley 700 F up-draft pressure carburetor or Bendix Stromberg QD–9A2. The main fuel valve of the Holley type is operated by two diaphragms according to the principles you studied in an earlier chapter. Since the chamber, formed by these two diaphragms, is completely filled with fuel at all times and the system is therefore not affected by gravity, the carburetor will function in any posi-



Left view of the Ranger V–770.

tion. This carburetor employs a variable opening venturi to control the air flow. Two throttles are located on opposite sides of a rectangular duct and are geared together. As the opening between them is varied, an almost perfect venturi shape is preserved at all times. Because of this feature the carburetor is practically free from icing troubles.

The Bendix Stromberg QD9–A2 carburetor is the pressure-injection type. Fuel is sprayed into the engine under a positive pressure rather than being drawn into the engine by suction at the throat of a venturi. This carburetor is also automatic, which means that it compensates for changes in the temperature and pressure of the entering air. Thus it delivers a constant fuel-air ratio for constant output of the engine regardless of air temperature or altitude.

SUPERCHARGER

The single stage, single speed supercharger is of the centrifugal type and is driven at nine and one-half times crankshaft speed. The supercharger draws the mixture from the carburetor and forces it into the intake pipes through two openings at either side of the supercharger housing. Each bank of cylinders has its own intake pipe system which increases the ramming effect of the supercharger.

IGNITION

The engine's ignition is provided by a single Bendix Scintilla DF–126 dual magneto, mounted on top of the rear section, and to the left of the starter-drive housing. The magneto has a single four-pole magnet rotating between two coils. It also has two separate contact breakers, one for

each coil, which are operated off the same breaker cam and are located in the contact breaker housing at the top of the magneto. This magneto therefore acts as a double unit and combines the added safety and improved performance of dual ignition with the light weight and simplicity of a single magneto. Since the use of a booster magneto has been found unnecessary, no provision has been made for it.

LUBRICATION

Engine lubrication is of the FULL PRESSURE type with a dry crankcase and external oil tank. A gear-type pump on the right side of the rear crankcase forces oil through an oil filter and a pressure relief valve. Part of the main oil supply is fed to the accessory gears in the rear section through a system of cast-in passages. Most of the oil, however, enters the accessory drive shaft which drives the accessories from the front end of the engine. This shaft lies at the lowest point of the main crankcase, between the cylinders, and acts as the main oil gallery. It supplies all main bearings with oil under pressure through vertical passages cast into the crankcase webs. From the main bearings, the oil passes into the crank pins through passages in the crank cheeks. Cylinder walls, piston, and piston pins are lubricated by splash from the crank pins.

PRESSURE OIL is supplied from the front end of the accessory drive shaft through cast-in passages to the various gears in the nose section, the reduction gear, and the propeller governor. Oil under pressure also travels through the hollow vertical shafts into the camshafts and provides pressure oil feed for the camshaft bearings. Small holes drilled between each pair of cams also provide an oil spray for the valve mechanism.

SCAVENGE OIL collects in the bottom of the crankcase and is prevented from running into the cylinders because the cylinder skirts project well above the bottom of the crankcase. This oil then drains through the two drive-shaft housings at the front, and through two main tubes at the rear, and collects in the cam housings, which act as oil sumps. A double scavenge oil pump is driven off the rear end of each camshaft. These pumps have two suction inlets, one connected to the front and one to the rear of each cam housing, so that scavenging is complete in either the nose-up or nose-down attitude. Both pumps return the oil to the tank through a common tube by way of an oil cooler.

PRE-FLIGHT INSPECTION

You've got orders to have that SO3C–2 warmed up and ready to take off at 0800. But before you start that engine, there is a mighty important preflight inspection which you must take care of. Always remember that a RELIABLE INSPECTION IS THE MOST IMPORTANT SINGLE THING YOU CAN DO TO MAKE SURE THAT IT FLIES HIGH, WIDE AND HANDSOME. You'll probably find a check-off list your most valuable aid in making a thorough inspection, but the following paragraphs cover the most important points—not only for your preflight inspection, but for your after flight inspection as well.

See that MAGNETO GROUND wires are properly connected, both at the magneto and at the switch. If one of these wires is loose, the engine is always on contact, even though the switch may be in the "OFF" position. And you don't want the engine starting accidentally.

Check the SPARK PLUG WIRES for cracks, chafing, oil soaking, and corrosion at distributor and

spark plugs. Make sure, too, that the plugs are screwed in tightly.

Examine FUEL AND OIL LINES for looseness, chafing or leaks, especially at fittings and connections.

Check CONTROL RODS, bell cranks and cables which work the throttle, mixture control, carburetor, and heater all the way from the cockpit to the engine. You should inspect controls for free movement, full travel in either direction, interference with other parts and whether they are connected correctly so that the action of the control is the same as indicated by the cockpit lever.

Check INTER-CYLINDER BAFFLES, front and rear baffles, and air scoop for proper fit, tightness and correct installation. When all these items have been checked, you can install the cowling but take care that all fastening buttons or pins are properly engaged.

Make sure before every flight that FUEL AND OIL in the tanks are at the proper levels, and that the tanks are filled.

Everything okay? Take her up then!

STARTING THE ENGINE

If the airplane is on the beaching gear, have the wheels checked. Make sure there is a fire extinguisher at hand. Turn on the battery switch. The main control panel is to the right of the seat. Check the fuel quantity on the gage at the lower right on the instrument panel. Whenever possible, the full load is carried in the bulletproof fuselage tank. Be sure to turn off the battery switch.

Check the oil level on the stick attached to the tank cap. This is reached through an access door held by two Dzus fasteners. Make sure the wingfold lock pins are locked.

Be sure the ignition switch is OFF. Then have the propeller pulled through three revolutions to be sure the cylinders are free of oil. Set the fuel selector valve to the tank you intend to use for take-off. Set the propeller pitch control in the high-pitch position for starting. Open the throttle about one-half inch to get a high idling speed of 800 to 1,000 rpm. Set the mixture control in the FULL RICH position. Set the carburetor air-heat control for COLD. Push it all the way in. Open the cowl flaps.

Now start the engine. Have a helper load the cartridge starter by reaching through the access door on the left side of the engine cowling. The breech opens when the arm is lifted. The cartridge is inserted and the breech closed tightly. Make sure, however, you use nothing larger than a type "A" cartridge. Extra starter cartridges are carried in a box on the left side of the pilot's cockpit.

Turn on the battery switch. The main control panel is to the right of the seat. Operate the wobble pump at the left of the seat until the fuel gage shows 6 to 8 pounds pressure. Push on the primer and turn the handle to the ON position. Prime the engine three to five strokes. Lock the handle in the OFF position. Get the "ALL CLEAR" signal from your helper. Then turn the ignition switch to the BOTH ON position. Close the starter switch for a moment.

If the cartridge fails to fire, wait a moment. Then close the starter switch again. If there is no action after three attempts, wait five minutes before opening the breech to replace the cartridge.

After the engine starts, your helper should open the breech lever part way to relieve the pressure. Then he should open it fully, remove the cartridge and close the breech.

If the oil pressure does not rise almost immediately, stop the engine and investigate.

WARM UP

When the oil pressure reaches 40 pounds (in about 30 seconds), place the propeller control in low pitch for high rpm for warm-up. Leave the cowl flaps open during warm-up. Keep the mixture control at FULL RICH. If the engine performs smoothly, run it up by easy stages to 1,500 rpm.

Check the fuel flow by switching the selector valve to each tank. The pressure may drop momentarily, but if it comes back to normal the fuel flow on that tank is O. K. If the pressure does not come back, use the wobble pump until the engine pump will hold normal pressure. If this does't work, you are out of gas or have fuel trouble.

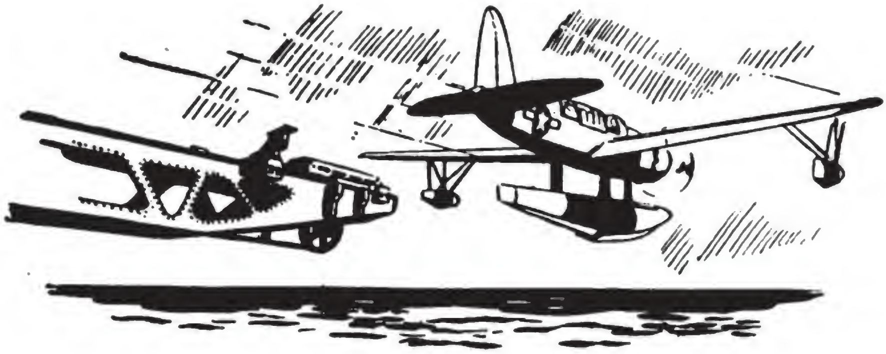
To check the propeller operation, adjust the throttle to 1,600 rpm. Move the propeller control from low pitch to high pitch. Do not move the throttle. A drop in rpm shows that the propeller governor is working. Keep the engine turning at 1,500 rpm until the oil-inlet temperature reaches 38° to 40° C. In winter, the oil temperature should reach at least 25° C.

Check the magnetos at 2,100 rpm by switching from BOTH ON to one magneto at a time. Be sure that the drop does not exceed 100 rpm. Check the oil pressure for 68 pounds desired (65 to 70) and fuel for 7 pounds desired (6 to 8). Check oil temperature for a maximum of 70° C.

Cylinder head temperature should exceed 100° C. and be below the maximum allowable of 270° C. for take-off.

You've learned already that this engine has a fully enclosed type of cowling. That's why the engine is much cooler immediately after a long glide than after several minutes of idling on the ground. So make sure the engine is not left idling after the airplane has landed. Shut it off as soon as possible.

When you're ready to stop the engine, you should have the cowl flaps "OPEN." Cylinder head temperature should not exceed 240° C. The propeller control should be put in LOW RPM POSITION (full up), and the mixture control should be put in IDLE CUT-OFF position. Snap switch off and on to check operation. After the engine has stopped, turn the ignition switch to the "OFF" position, shut off the fuel valve and turn off the master switch.



CHAPTER 11

PRATT AND WHITNEY WASP JR.—R–985

WHAT IT IS

During the first phase of the North African Campaign a Naval observation airplane was attacked by three enemy fighters while spotting hits for a battleship. Ducking in and out of the clouds, with a clever pretense of panic, the pilot led the Axis fighters back toward his ship.

At the last moment, he dived out of a cloud with the three planes on his tail. Antiaircraft gunners opened up before the enemy pilots could pull out and in two minutes all three fighters had been shot down. Then the observation pilot calmly went back to spotting for the big guns.

That was his job, for the scout observation pilot evades combat, confining his activity to the main function of spotting the enemy. The scouts are the long range eyes of the fleet. They pierce the enemy's line to unveil their movements. Their quick reports or warnings may lead to a spectacular victory. Much of the scouting work is, of course, monotonous routine but nevertheless vitally important.

The scout-observation airplanes, more commonly on floats than wheels, are built ruggedly to with-

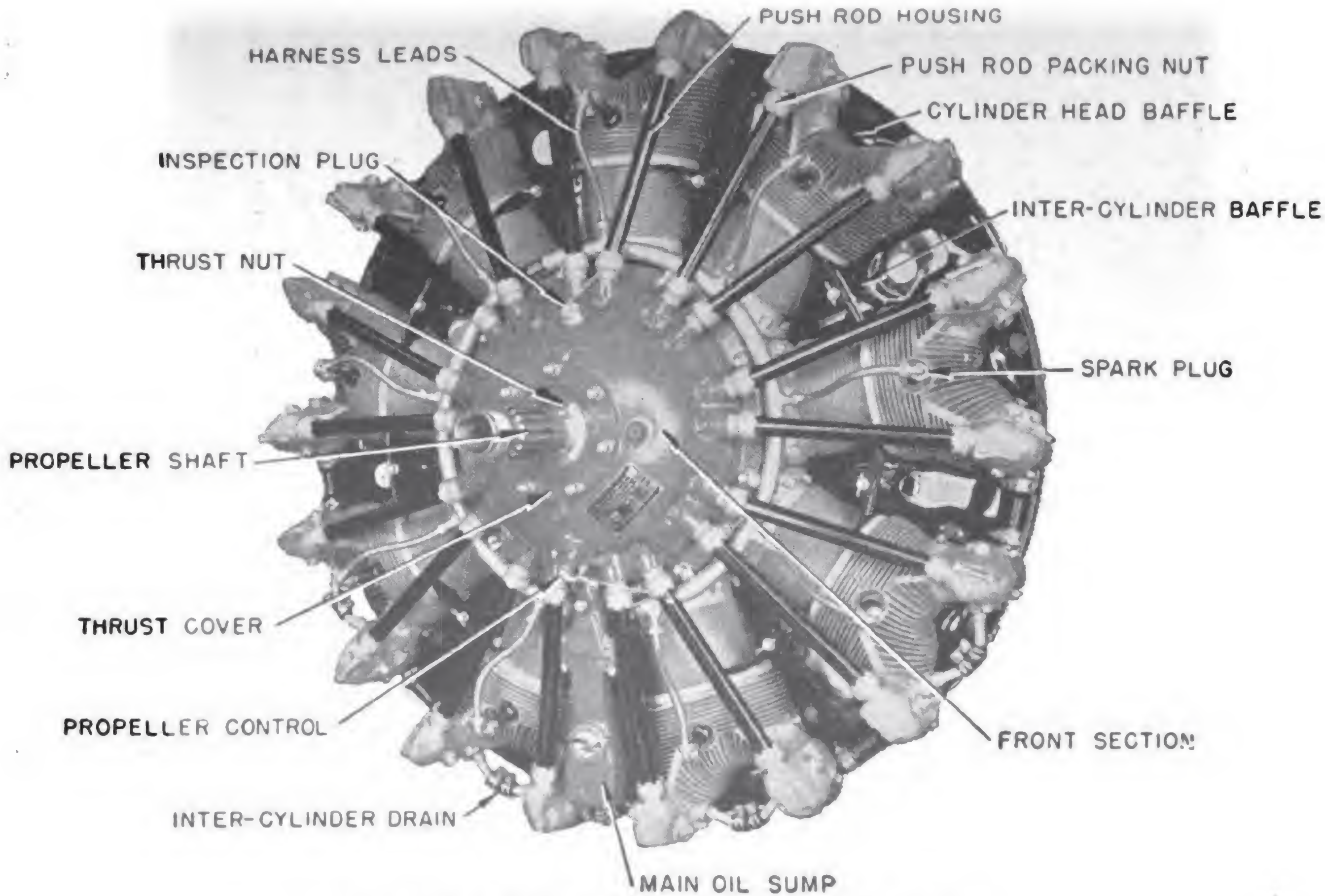
stand rough water landings. They are necessarily slower than fighters and their armament and protection are somewhat reduced to give them longer range. Such an airplane is the OS2U-3 Kingfisher. Its job is to look and run.

You'll find this airplane equipped with a Pratt and Whitney R-985 direct-drive engine, rated at 400 horsepower at sea level. It is radial in construction, has nine cylinders and a single-stage, single-speed supercharger. The engine weighs approximately 675 pounds. Its general features include a solid master rod and two-piece, split-pin crankshaft, a forged aluminum alloy main crankcase of two sections, a built-in supercharger, automatic valve-gear lubrication and an updraft carburetor.

ENGINE PARTS

All valves are opened and shut by means of a cam ring as were those you have studied earlier in this book. The cam ring operates the valves through two four-lobed tracks. It is rotated to crankshaft direction at one-eighth crankshaft speed. You'd guess that this reduction in speed would be accomplished by some gear arrangement connected with the crankshaft. You're right. It's done by means of a train of spur gears and internal teeth on the cam ring itself. The CRANKSHAFT is a single throw, two piece, split-pin type, supported by three bearings. The front section of the crankshaft is splined to the rear and is held together by a through bolt. The MASTER ROD is one-piece and has a pressed-in, steel-backed, leaded-silver bearing. All PISTONS are made of aluminum alloy forgings and are of the full skirt type.

The CYLINDERS are of steel and aluminum. Cooling fins are built in the barrels which are ma-



Front view of the Pratt and Whitney Wasp Jr. R–985.

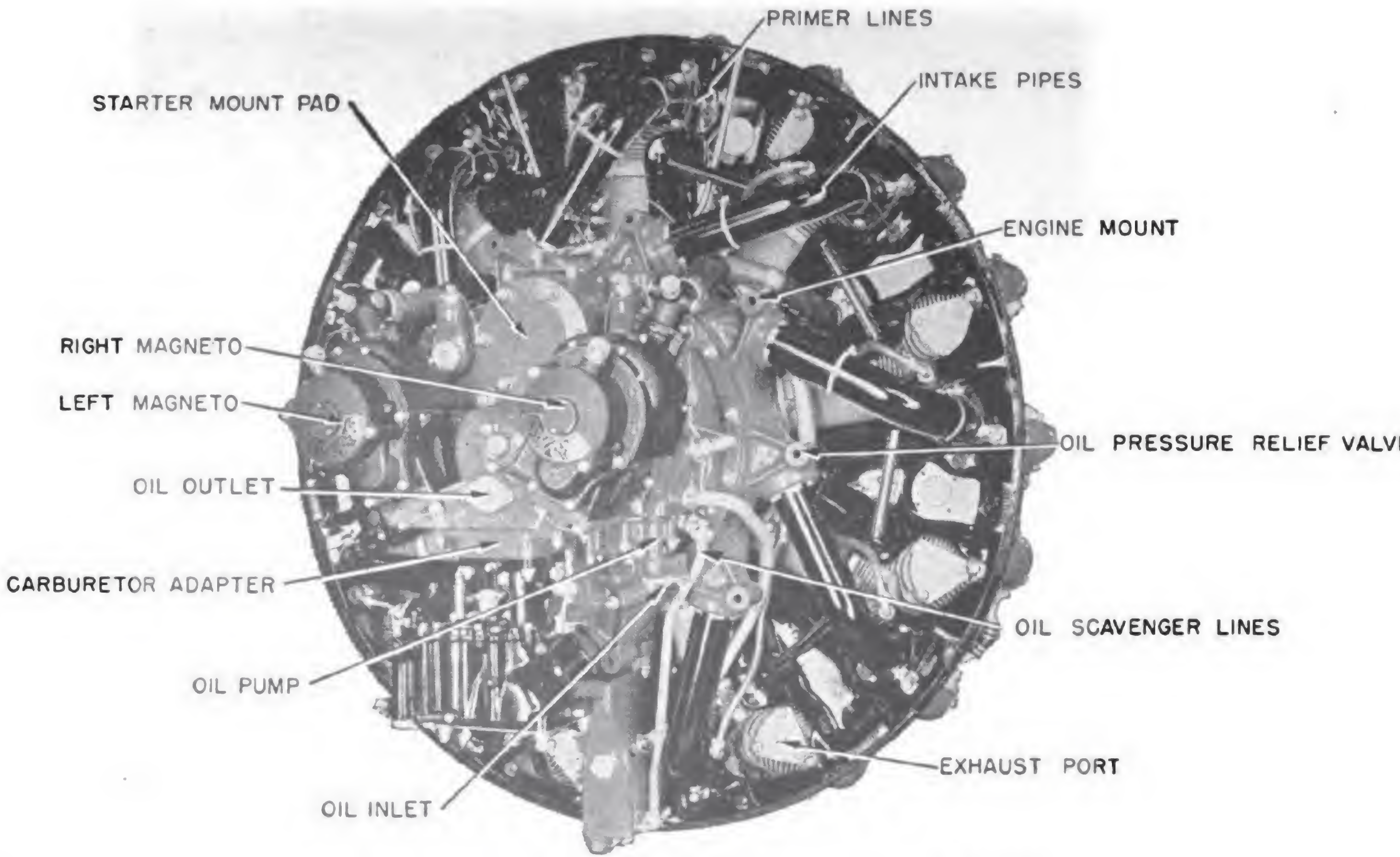
chined from steel forgings. Closely spaced cooling fins are also built in the aluminum alloy heads. Each cylinder has one inlet and one exhaust valve. As you know, proper cooling of the exhaust valve is of great importance. Consequently the fins are concentrated at the exhaust side of the heads and also at the top of the head, where rapid heat dissipation is most essential.

The VALVE OPERATING PARTS are enclosed. The rocker arms are housed in rocker boxes. Eighteen tappets, located in the front main crankcase (nose section), move the rocker arms through tubular push rods with hardened steel-ball ends. Two valve springs are attached to each valve stem by a split cone and washer. It's worth noting that YOU CAN REMOVE THESE SPRINGS WITHOUT TAKING OUT THE ROCKER ARM. The entire valve mechanism is pressure lubricated by oil which enters the tappets through the guides and flows from there through the hollow push rods and rockers.

The SUPERCHARGER is in the blower section at the rear of the main crankcase. It is of the centrifugal type, with which you're familiar, and is driven by the crankshaft through a spring coupling. The spring coupling relieves the blower gears of sudden strains from rapid acceleration or deceleration. This coupling is located inside the rear crankshaft gear which in turn couples with a floating gear in the blower section. The impeller is driven at 10 to 12 times crankshaft speed by a pair of spur gears.

CARBURETOR

The R–985 engine is equipped with a Stromberg carburetor. This is a single barrel, updraft, float carburetor similar in principle to the one you studied earlier in this book. It has the back suc-



Right rear view of the Pratt and Whitney Wasp Jr. R–985.

tion type of automatic mixture control. The accelerating pump is linked to the throttle and can be used to prime the engine before starting.

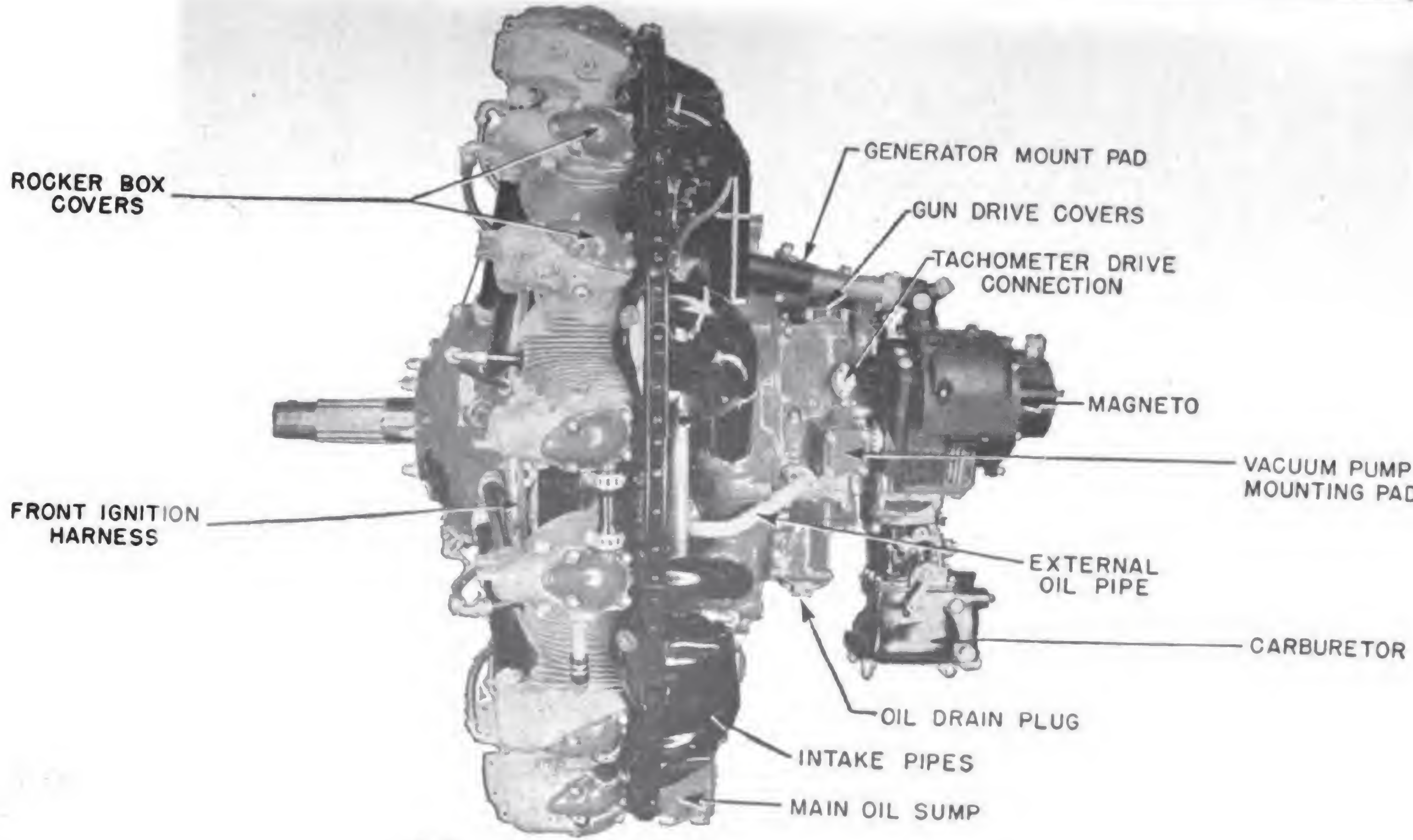
IGNITION

Two American Bosch magnetos provide the ignition. These are located at the rear of the engine. Each fires one of the two spark plugs in each of the nine cylinders, thus giving two independent sources of ignition. The right magneto fires the front spark plug in each cylinder and the left magneto fires the rear spark plug in each cylinder. The ignition harness and spark plugs are of the shielded types to prevent radio interference.

LUBRICATION SYSTEM

A three-section gear pump circulates oil through the engine. This pump is mounted in the right-hand lower side of the rear section. Oil from the tank enters the oil inlet at the bottom of the pump, and is directed to the pressure (lower) section of the pump. From there it is forced to the oil screen chamber, located directly forward of the carburetor. The oil is then directed through the blower section to the front of the engine. A cored passage conducts oil to the oil-pressure relief valve at the right side of the rear section where the engine oil pressure is regulated. By-passed oil is returned to the inlet side of the oil-pump pressure section.

Branch lines from the strainer chamber circulate oil for the lubrication of the accessory drive bushings, gears, and accessories in the rear section. The oil is conducted through the lower part of the main crankcase section and then to the main oil transfer bracket. At this point the oil is introduced into the crankshaft by means of the oil



Left view of the Pratt and Whitney Wasp Jr. R–985.

transfer bracket where a drilled passage in the crankshaft directs it to the crankpin for the lubrication of the master rod bearing, knuckle pins and bushings, piston pins and bushings and cylinder walls. The cylinder walls and piston pins and bushings are lubricated by spray from oil jets—in the front crankshaft and the rear cheek—and also from oil which passes the master rod bearing and knuckle pin bushings.

Oil from the main oil transfer bracket is piped to a two-positioned valve in the nose section. From there it is introduced into the propeller shaft through an oil transfer for the operation of a hydro-controllable propeller. An oil manifold ring fastened to the tapped bosses on the front section conducts the oil to the tapped guides. Oil is then fed into the tappets and through the push rods to the rocker arms, rocker arm bearings, and valve clearance adjusting screws.

The surplus oil in the engine proper drains into the main sump. Oil from the rocker boxes drains through the push rod cover tubes to the crankcase or through a system of inter-cylinder drain pipes to an additional compartment in the sump. From there it is pumped through the scavenging pump to the oil tanks.

INSPECTIONS

Before you ever okay an engine for flight, you should make a line inspection. However, you should make more complete inspections periodically. The manufacturers of this engine have recommended that it be given a thorough check 15 to 30 hours after installation in the airplane. After that, the length of time between inspections will depend largely upon operating conditions. But you will find that checks at 50- to 75-hour intervals are recommended for the average case.

In wartime, however, the heavy strain put on an engine may make thorough inspections necessary more often. For these, you'll probably use a check-off list on a PERIODIC INSPECTION FORM. But remember that BEFORE and AFTER EACH FLIGHT you should always make careful line inspections.

The AFTER-FLIGHT inspections of the engine on the OS2U–3 should be made when the airplane lands after a day's flying. Here are the major items on the after-flight check-off list—FUEL, OIL, IGNITION, SECURITY OF PARTS.

Now let's see just how you would make this inspection. Refuel the airplane with gasoline of at least 92-octane rating. DO THE JOB THE SAFE WAY. Put the caps on and tighten them. Unhook the cowl flaps so you can reach the oil tank caps. Fill the oil tank to the rated capacity (10 gallons) only. Put the tank cap back securely. Be sure you hook the cowl flaps after you add oil. If you do not hook them, the pilot can't open the flaps and might burn out the engine.

Take off cowl panels so you can reach the engine. Check the cowl flaps and cowl flap hinges for cracks and worn hinge bolts. Examine the cowl lever hinges. See that they are in place and fastened securely. Inspect the collector ring and the exhaust stacks. See that they are securely attached, and that there are no cracks. Make sure the engine mount bolts are tight and the cotter pins are in place. Look to see if they are stretched or show other signs of wear and failure.

See that all the ignition wiring and harness you can easily get at is securely mounted. Make your check in ALL nine cylinders—both front and rear. Check the spark plug terminal assemblies. Make sure the plugs are clean and tight. Look for oil at the cylinder bases, crankcase joints, and on all accessories. Check all lines and wires to make

sure of correct clearance. Check all connections for security. Check the oil lines and fuel lines for leaks. Oil lines have a YELLOW band—fuel lines have a RED band. Be sure all tools and rags used are taken from the airplane.

In all parts of the airplane, keep your eyes open for loose or missing nuts, cotter pins, safety wire or any foreign objects. Check the throttle, mixture control, propeller control, and carburetor air-heat control for freedom of movement and range of operation. See that they are securely attached. Check the instruments and their connections. Put the cowling back on. Inspect each panel and fasten it securely in place. Check the Dzus fasteners. Make sure all the slots are pointing in the same direction.

On your PRE-FLIGHT inspection you should check the following items—

FUEL SYSTEM, OIL SYSTEM, COWLING, PROPELLER, AND INSTRUMENTS.

First, pressure-check the main screen by operating the wobble pump one or two strokes. Watch the fuel pressure gage. It should read 3 to 5 pounds pressure. If pressure does not show on the gage, gasoline is not going through the main screen. Drain a small amount of fuel from the main strainer. Switch the fuel selector to one tank after another to make sure that the lines are open. Take out the main fuel strainer screen. Flush it with kerosene and blow it out with air. Check the screen for cracks. THIS SCREEN IS DAMAGED EASILY. Therefore, handle it very gently. Put the strainer back and safety it.

Check again for leaks in the oil lines and fuel lines. Check the cowling. Make sure the panels are securely attached. Inspect the propeller blades for pits, cracks, and nicks. Look for signs of oil leakage. See that the propeller hub bolts

are tight and safetied. Use the oil tank cap gage to check for correct level. Hook up the cowl flap after this check. Measure the gasoline with a stick to get an accurate reading on the fuel tanks. Make sure the ignition switch is OFF. Then pull the propeller through at least 3 revolutions to clear the cylinders.

Test the throttle, mixture control, propeller control, and carburetor air-heat control for freedom of operation. Look over the engine instruments for broken levers and indicator pointers.

STARTING THE ENGINE

Before you make a move to start the engine you should be sure the ignition switch is OFF and that the brakes are set. You should also have a fire extinguisher at hand.

Check the oil level of the stick attached to the tank cap. This is reached through the cowl flap opening. Turn on the battery switch and check the fuel quantity on the gage at the lower right on the instrument panel. Then turn off the battery switch.

Let your helper pull the propeller through three revolutions to clear the combustion chambers of oil or gasoline. Pull out the control handle to set the propeller at positive high pitch. Open the cowl flaps. Turn the fuel selector valve to RESERVE. Set the mixture control for AUTOMATIC RICH. To release the mixture control lock, press the small button in the center of the knob. Be sure the latch drops into the proper slot. Set the throttle about one-half inch open to get high idling speed. Put the carburetor air heat control in to FULL COLD position.

Now you're ready to start the engine. Lift the lever to open the starter breech. Put in the cartridge. Close the breech fully and lock it.

And make sure you never use a cartridge containing over 17 grams of powder (type B). Operate the wobble pump to get a reading of three pounds on the fuel pressure gage and keep up this pressure until the engine is running smoothly. Prime the engine five strokes for cold starting—or two strokes for warm starting. Don't prime when the engine is hot.

Turn on the battery and generator switches. Get the "all clear" from the mechanic. Turn the ignition switch to BOTH. Turn the starter switch ON for a moment. If the cartridge fails to fire, do not remove it from the breech for at least 5 minutes. After starting, raise the breech lever only half-way. Let any pressure in the starter escape through the relief valve. Then unlock the breech fully, remove the cartridge, and close the breech. If the oil pressure does not register on the gage almost immediately, stop the engine and see what's wrong. As soon as the engine is running smoothly, push in the propeller control to get low pitch for high.

WARM UP

Set the throttle to get 1,000 rpm during the warm-up until the oil temperature is over 40° C. Do not go over 1,200 rpm except for short periods. At about 1,550 rpm, switch from both magnetos to one at a time and note the loss of revolutions. A drop-off of more than 100 rpm shows that something is wrong. Make this check in as short a time as you can to avoid fouling the plugs. Turn the fuel selector valve to each tank long enough to be sure the engine will hold normal fuel pressure (3 to 4 pounds) on each tank. For a check of engine operation, open the throttle briefly to 30 inches Hg manifold pressure. Check the oil pressure, oil temperature, fuel pressure, and rpm.

During warm-up, hold the cylinder temperatures to a maximum of 204° C. Even during short bursts, never go over 260° C.

This completes the steps in starting and warming up the engine. Just before launching the airplane, though, you should check the oil temperature again. This should be 25° C. minimum. It should never go over 95° C. at any time. Oil pressure should be between 70 and 90 pounds per square inch. Fuel pressure should be at 3 or 4 pounds per square inch. Check again the loss of rpm when switching to one magneto at a time. Normal drop-off is from 50 to 75 rpm. At this point, the cylinder head temperatures should be above the minimum of 120° C., but still low enough so that the take-off power will not send them beyond the maximum limit of 260° C.

STOPPING

Open the cowl flaps to cool engine while idling. Pull out the propeller control handle (for positive high pitch) if practicable. Close the throttle when engine has cooled. Pull back the mixture control to the limit of movement. Turn the ignition switch to OFF when the engine has stopped. Turn off battery and generator switches.

CHAPTER 12

WRIGHT CYCLONE R–1820

WHAT IT IS

One of the Navy airplanes which has been most effective in making Jap admirals shiver on their bridges is the SBD–3, Douglas Dauntless. This scout bomber not only flies on long scouting missions, but once freed of scouting activities, can carry bombs in its racks and go on attack missions. Then, of course, there are the combination search-attack missions.

You can see that such a double service airplane must be rugged in structure and powered by a sturdy engine of diversified performance. The engine that does this job for the SBD–3 is a radial nine-cylinder, single-row, Wright Cyclone, R–1820. It is air-cooled and has a single-stage, two-speed supercharger.

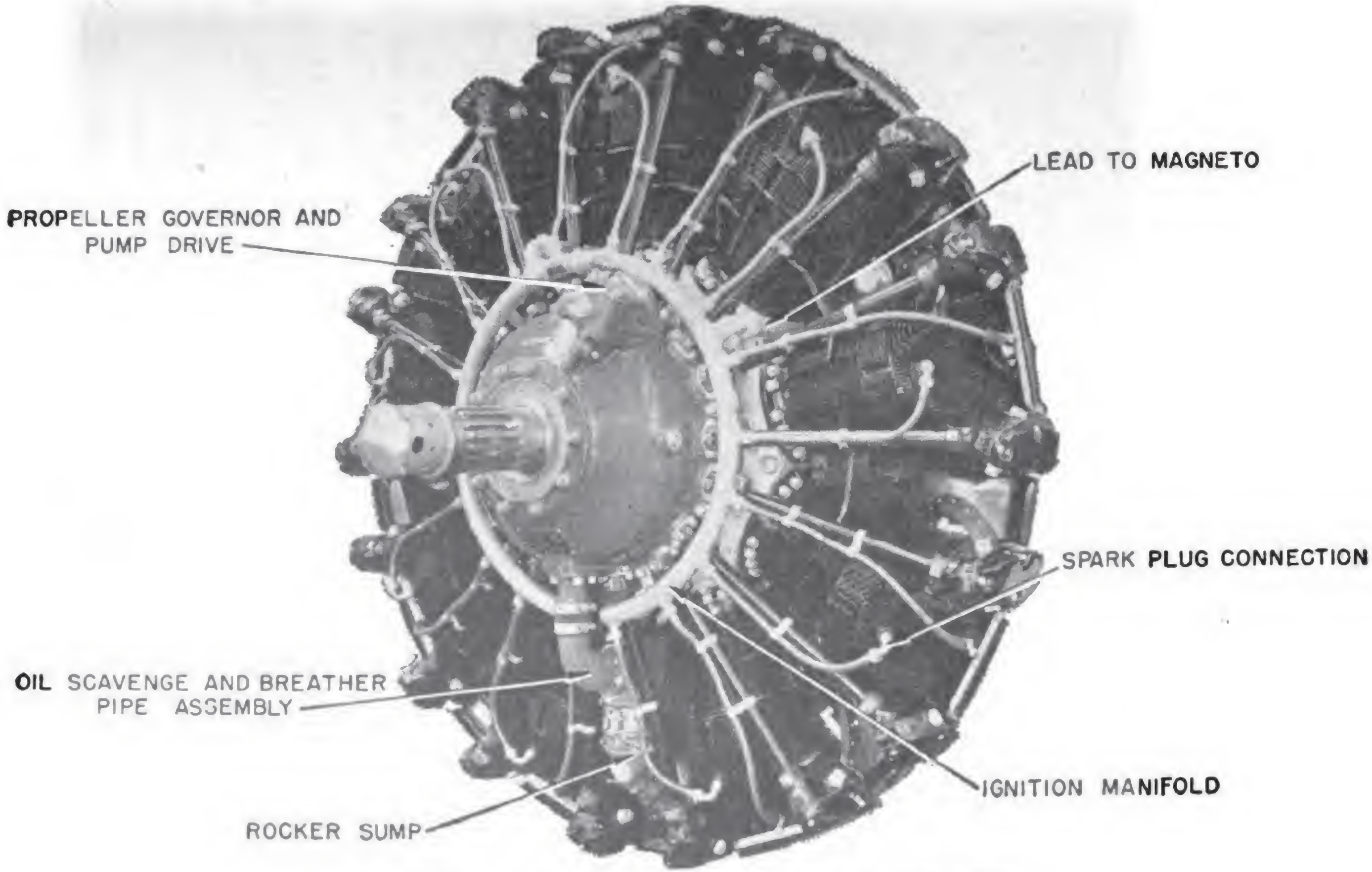
ENGINE PARTS

The CYLINDERS are built up by shrinking threaded, cast aluminum-alloy heads on forged steel barrels. The exhaust-port boss faces toward the rear of the engine and is provided with four studs for securing the exhaust stacks. The intake-

port boss is at the rear of the cylinder head and faces toward the right and slightly downward, toward the center of the engine. This arangement allows smooth, uninterrupted flow of mixture to the cylinder. The valves are inclined at an angle to the axis of the cylinder. The valve seats and the valve stem guides are shrunk into the cylinder head. The valve guides are made of bronze. Two bronze spark plug bushings are screwed and pinned in the front and rear of the cylinder head. They are in the same plane through the cylinder axis, but inclined so as to be 90° to each other. The CYLINDER BARREL has integral cooling fins and is machined from a steel forging.

The CRANKSHAFT is of two-piece construction, single throw type, and is machined from alloy-steel forgings. The front section of the shaft includes the drive shaft, the front crankcheek and counterweight and the crankpin. The rear section is composed of the rear crankcheek, dynamic damper counterweight and crankshaft rear-bearing journal. The crankpin and drive shaft are bored for lightness. The dynamic damper is in principle, a pendulum counterweight instead of the conventional rigidly mounted counterweight. Two floating pins, which pass through the extended section of the rear crankcheek, support the counterweight.

This type of engine is equipped with planetary REDUCTION GEARS. The unit consists essentially of a reduction driving gear or crankshaft gear splined to the crankshaft. These form a bearing for the cam pinion gears, which are mounted on the legs of a spider, and for the stationary spur gear, which is fastened to the nose section. The pinion gears mesh with the crankshaft gear and the stationary gear.



Three-quarter front view of the Wright Cyclone R–1820.

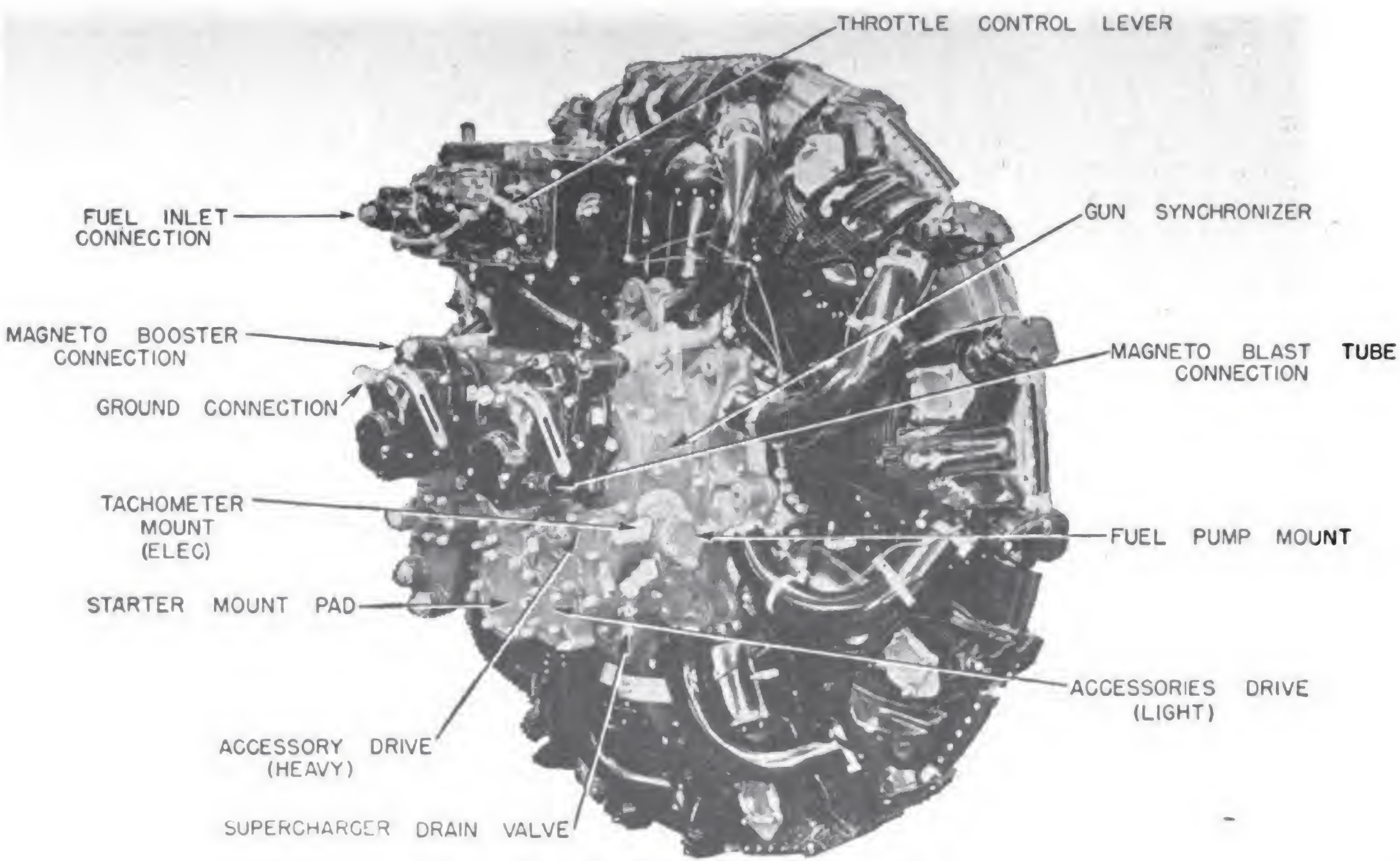
The CONNECTING ROD assembly consists of a master rod and eight articulated rods attached to the master rod by knuckle pins. The rods are fabricated from a special alloy-steel forging, heat-treated for high strength and machined all over. The master rod operates in the No. 1 cylinder in most engines of this series, although in some cases it has been shifted from the standard position for special reasons. You can always find out in which cylinder the master rod operates by looking at the engine data plate.

The PISTONS are full trunk type, machined from aluminum-alloy forgings. They have five ring grooves, four above the piston pin and one below. Each of the upper three grooves in this series of engines is provided with one compression ring. Two oil-control rings are placed in the fourth groove, and an oil scraper ring is installed in the bottom groove.

The VALVES receive their motion through a cam in the crankcase front section. The cam consists of a hardened steel ring with two sets of cam lobes on its periphery (rim). The cam ring is secured to a lightweight hub provided with a bearing which rides on a journal integral with the reduction driving gear.

The CAM DRIVE consists of a gear on the crankshaft and a cam drive gear and pinion, which rotate on a journal that is fixed at the forward side of the crankcase main section. The cam drive gear meshes with the gear on the crankshaft, and the pinion meshes with the internal gear on the four lobe cam ring, thereby driving the cam at one-eighth crankshaft speed and in the opposite direction.

The CAM LOBES acting on the cam follower rollers or valve tappets actuate the pushrods and



Right rear view of a Wright Cyclone R-1820.

they, in turn, operate the rocker arms which open the valves.

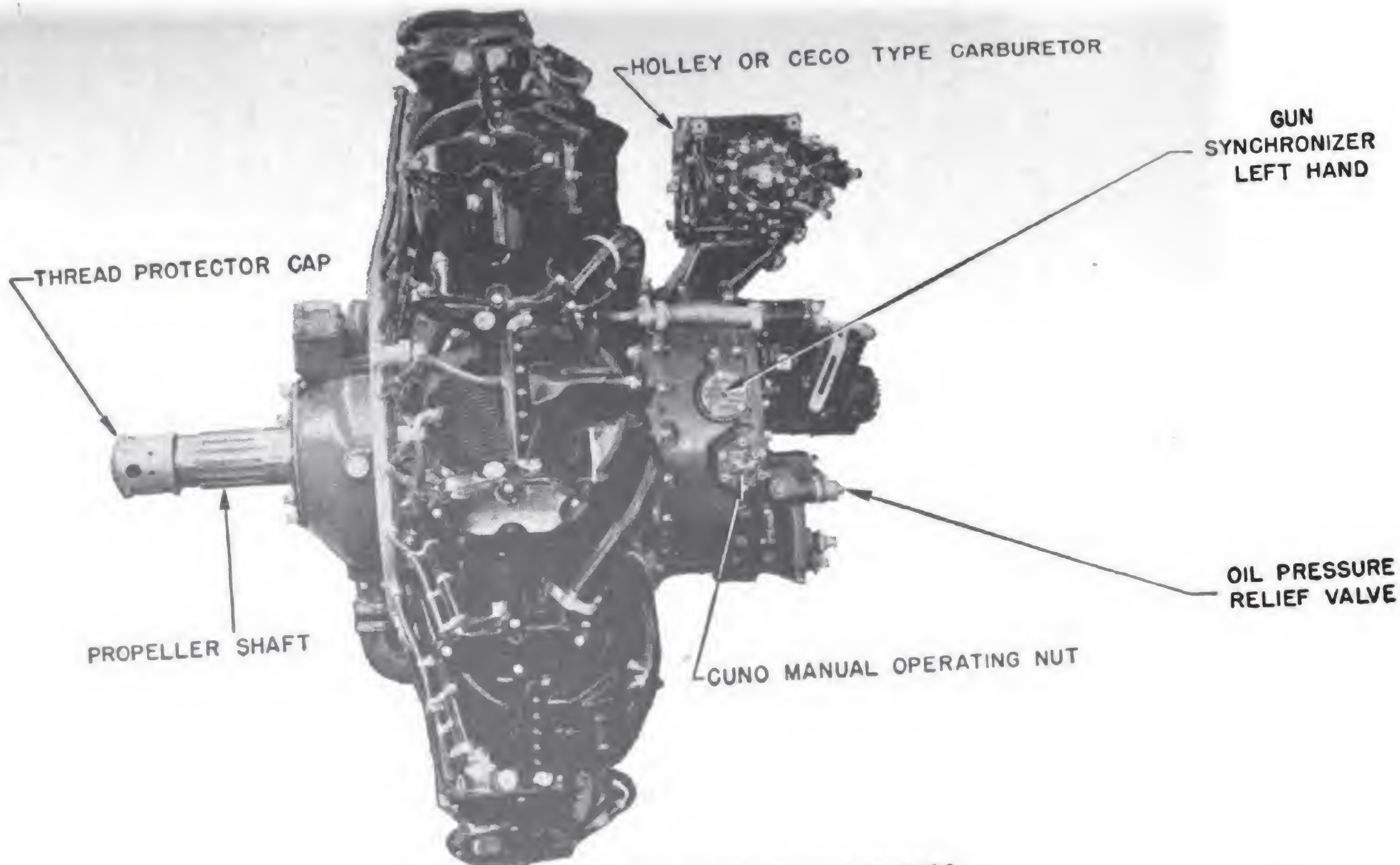
The INTAKE VALVES are of the tulip type and the exhaust valves are of the mushroom type. Both are machined from forgings of heat-resisting steel. The exhaust valve is of the sodium-cooled type, while the intake valve stem is smaller in diameter and is of solid cross section. Each valve is fitted with three concentric coil springs.

SUPERCHARGER

The SUPERCHARGER on this engine is of the centrifugal type such as you have found on most Naval aircraft engines. It consists of an impeller, a diffuser and distribution chamber. The impeller is machined from a duralumin forging. It is mounted on a hollow steel shaft with one plain bushing pressed inside each end. The diffuser chamber is a narrow annular ring-shaped passage containing fixed vanes surrounding the impeller. The mixture is discharged through this passage into the distribution chamber. The intake pipes are attached to this chamber through ports on the outside. A drain passage is provided from the lower portion of the supercharger inlet chamber through the rear housing, to prevent the accumulation of excess fuel.

CARBURETOR

Engines in this series (Cyclone G) may be equipped with either a Stromberg or a Holley carburetor. The model R–1820–52, which powers the SBD–3, is equipped with a Holley carburetor. It is mounted on the top of the supercharger rear section since this engine has a down-draft fuel induction system. This carburetor has a single air passage controlled by a variable venturi.



Left view of the Wright Cyclone R–1820.

A diaphragm mechanism, replacing the conventional float device, admits fuel to a supply chamber. The controlled pressure differential produced by the variable venturi causes fuel to flow from the supply chamber to the metering nozzles in the venturi throat. You'll find in actual experience that this carburetor is free of ordinary icing troubles.

MAGNETOS

Two Scintilla Magnetos, mounted on the rear cover, provide the ignition. The right hand magneto fires the front spark plugs, and the left hand magneto fires the rear spark plugs. All parts of the ignition system are shielded against radio interference.

LUBRICATION

The lubrication system is of the full-pressure type except for the cylinder walls, piston pins, and crankshaft roller and ball bearings. These are lubricated by splash. Oil is carried in an external tank, furnished with the plane, not with the engine. The oil is drawn from the supply tank by a pump mounted on the left side of the rear cover section. The engine-oil pump used on Cyclone engines is provided with a spring-loaded piston-type relief valve which lifts from its seat when the desired pressure is reached and delivers excess oil to the inlet side of the oil pump. You should refer to the Wright Instruction Book and to a lubrication chart in order to get a thorough uderstanding of the flow of oil and the lubrication process in this engine. All return oil drains to a sump located between cylinders 5 and 6. From there it is pumped to the oil tank by the oil scavenge pump.

First, let's see what checks are made by the ground crew AFTER EACH DAY'S FLYING. Remember, though, that before you start any inspection you should chock the wheels and ground the airplane. Be sure the switch is OFF!

Refuel the airplane with 100-octane gasoline. Be careful and follow the rules of safety. Tighten the gas tank caps. Fasten the access doors tightly. Fill the oil tank to the rated capacity only. In the combat condition, the oil tank has a service capacity of 16.5 gallons, plus three gallons of foaming space. Be sure the tank cap is tight when you replace it.

Take off the accessory cowling and the nose ring. Look for cracks in the engine mounting. Check the mount for security. Check the exhaust rings for cracks and for security. Look down into the carburetor air intake. Make sure that it is clear. Check the tightness of the ignition cables and terminals. Be sure that the ignition harness is secure. Inspect the cylinder baffles. See that they are not loose or cracked. Check all fittings and tube connections for tightness. Also check the accessories for tightness and security.

Check the oil, fuel, and hydraulic lines for leaks. Oil lines are marked with a YELLOW band. Fuel lines have a RED band. Hydraulic lines have BLUE-YELLOW-BLUE bands. Look for the blue stains made by 100-octane aviation gasoline around fuel line fittings. Such stains show that there is a leak. Check the ignition switch again to be sure the ignition switch is OFF. Then look over the front gear section of the engine for oil leaks. Check the propeller for pits or cracks.

Keep your eyes open throughout your inspection for loose or missing nuts, cotter pins, or

safety wire. Put the cowling back on. Inspect each panel and fasten it in place. Check the throttle, mixture control, propeller control, supercharger blower control, and carburetor air-heat control for freedom and range of movement, and for security. This completes the after-flight engine inspection.

Now let's see what checks to make in the PRE-FLIGHT INSPECTION. First, be sure to ground the airplane and be sure the switch is OFF. Take off the cowling just as you did for the after-flight inspection. On the SBD-3 the A. E. L. unit near the oil cooler radiator is the main sump of the fuel system. Take the safety wire off the drain coils. Be sure the fuel selector valve is OFF. Drain the unit to get rid of any moisture which may have collected. Take out the strainer screen. Clean it with an approved cleaning fluid, and dry it with an air blast. Put the screen back in the A. E. L. unit. Secure the drain cock and hinged clamp with safety wire.

Check carefully for leaks in the fuel and oil lines. On the SBD-4 a fuel strainer unit takes the place of the A. E. L. unit. Drain the strainer to get rid of any moisture. Take out the strainer screen. Clean it with an approved cleaning fluid and dry it with an air blast. Put the screen back in and secure the strainer unit with safety wire. Put the cowling back on. Make sure that the panels are on tight. Check the propeller. Look for pits, cracks, and nicks. Look for signs of oil leakage. Take a reading on the fuel tanks with a calibrated stick. Put back the filler cap, and close the inspection door. Use the oil tank cap gage to check for correct oil level. Don't forget to replace the cap and close the access door. Check the engine controls for freedom of movement. Look for leaks around the fuel primer.

Be sure that the wheels are chocked. Have a fire extinguisher at hand. Make sure that the crew is clear of the propeller.

Turn on the battery switch. The main electrical control panel is in front of the pilot, below and to the right of the instrument panel. Check the fuel gages at the lower right side of the instrument panel. The fuel load in this airplane is carried in four self-sealing wing tanks.

DON'T FORGET TO TURN OFF THE BATTERY SWITCH! Check the level of the hydraulic fluid in the reservoir in the pilot's cockpit. Make sure that the system is full.

BE SURE THAT THE IGNITION SWITCH IS OFF. Then have the propeller pulled through three revolutions to be sure that the cylinders are free of oil. Except in cold weather, open the air cooler air scoop. Turn the small crank below the instrument panel until the indicator shows that the scoop is open. Set the fuel selector valve to RIGHT MAIN or to RESERVE tank. This valve is to the left of the pilot's seat.

If the airplane has a constant-speed propeller, set the propeller pitch control in the high-pitch position for starting. If the airplane has a hydromatic propeller, set the propeller pitch control in the low-pitch position for starting. Open the throttle control about 10 percent to get an idling speed of approximately 600 to 1,000 rpm. Set the mixture control to the AUTOMATIC RICH. The mixture control is fitted with a latch lock to prevent accidental movement or creeping. To move the control, release the latch by lifting it up. Set the supercharger blower control at LOW BLOWER. Set the carburetor air control at DIRECT. The control handle must be in. This gives a direct flow of air to the carburetor. Open the cowl

flaps. Set the control lever in the OPEN position. Pump the flaps open with the hand hydraulic pump. Then return the control lever to the NEUTRAL position. The cowl flaps must be open during warm-up to prevent overheating.

Now let's start the engine. Turn on the battery switch and the generator switch. Have a helper energize the starter. This airplane has a Bendix inertia starter. It is energized with a hand crank. The starter crank is stowed in the baggage compartment. On the SBD–3 operate the wobble pump at the left of the seat until the fuel pressure gage shows 6 to 7 pounds of pressure. On the SBD–4 fuel pressure is developed by an electric fuel booster pump. Turn on the booster pump switch. If the engine is cold, push on the primer and turn the handle to the ON position. Prime the engine with two or three full strokes. Do not overprime.

If possible, priming the engine should be done while the starter is being energized. In this way, raw fuel remains in the engine for the shortest possible time. Lock the handle in the OFF position. The handle must be in the OFF position at all times, except when you are operating the primer. When the "all clear" signal is given by the mechanic, turn on the ignition switch. Then pull out the starter engaging handle.

WARM UP

During the starting process, the throttle SHOULD NOT be pumped to keep the engine running. On SBD–3's, which do not have a booster pump, it is sometimes necessary to operate the wobble pump to keep the fuel pressure up while the engine is starting. If the oil pressure does not build up almost immediately, stop the engine and investigate. With a constant-speed propeller, when the oil

pressure reaches 50 pounds (in about 30 seconds), put the propeller in LOW PITCH for high rpm. WITH A HYDROMATIC PROPELLER, THE ENGINE IS STARTED IN LOW PITCH. Start the warm-up with the propeller turning about 800 to 1,000 rpm.

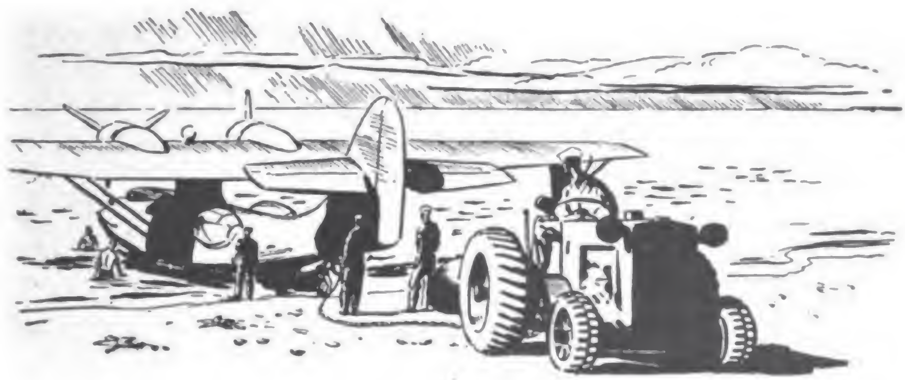
In completing the warm-up, don't exceed 1,000 rpm until the cylinder head temperature is above 100° C. and the oil temperature is above 40° C. Keep the mixture control at AUTOMATIC RICH. Move the propeller control from low to high pitch several times to warm up the oil in the hub cylinder. If the propeller governor is working right, there will be a drop in rpm as the control is moved to high pitch. Check the magnetos at a manifold pressure of 30 inches of Hg by switching from BOTH to ONE magneto at a time. The drop should not be more than 100 rpm. Check the oil pressure for 60 to 80 pounds, and fuel pressure for 6 to 7 pounds. Check the oil temperature for a maximum of 80° C. Cylinder head temperature should be greater than 150° C. and less than 260° C. for take-off.

STOPPING THE ENGINE

To stop an engine with a CONSTANT-SPEED propeller, first turn it up to 1,200 rpm. Keep it running at this speed for at least 30 seconds. Move the propeller pitch control from the LOW-pitch to the HIGH-pitch position. When the engine loses 500 rpm, move the mixture control back to the idle-cut-off position. This works the idle-cut-off valve which stops the engine.

To stop an engine with a HYDROMATIC propeller, leave the propeller in low-pitch position with the engine running about 800 to 1,000 rpm. Then move the mixture control to idle-cut-off position. If your airplane is an SBD–4, turn off the fuel booster pump.

Never try to stop the engine by turning off the fuel valve. This would suck air into the fuel line. When firing stops, push the throttle wide open to clear the cylinders. After the propeller stops spinning, turn off the ignition switch. Turn off the battery and generator switches. Turn the fuel selector valve to the OFF position. Leave the mixture control in the idle-cut-off position.



CHAPTER 13

PRATT AND WHITNEY TWIN WASP R–1830

WHAT IT IS

The oldest patrol bomber in operation in the Navy is the Catalina Flying Boat, PBY–5, which is still used widely. You have read of the exploits of the PBY's in the Aleutians, of daring Arctic rescues and of night bombing attacks in the Southwest Pacific. The Catalinas have proved themselves in all theaters of war.

Also in this same seaplane category is the PBY–5A, (an amphibian version of the PBY–5). These airplanes go on long patrol missions to obtain early and accurate information of the enemy. They have been used extensively in convoy guarding and antisubmarine patrols. Their all-important work goes on ceaselessly—in fair weather and foul, in summer and in winter, from bases in Iceland, Greenland, Newfoundland, Alaska, and in the Southwest Pacific.

The Catalina is powered by a twin row radial, 14-cylinder, single-stage, single-speed supercharged, air-cooled engine, weighing about 1,465 pounds. This engine, the R–1830–92 model, is powerful and dependable. It was built to with-

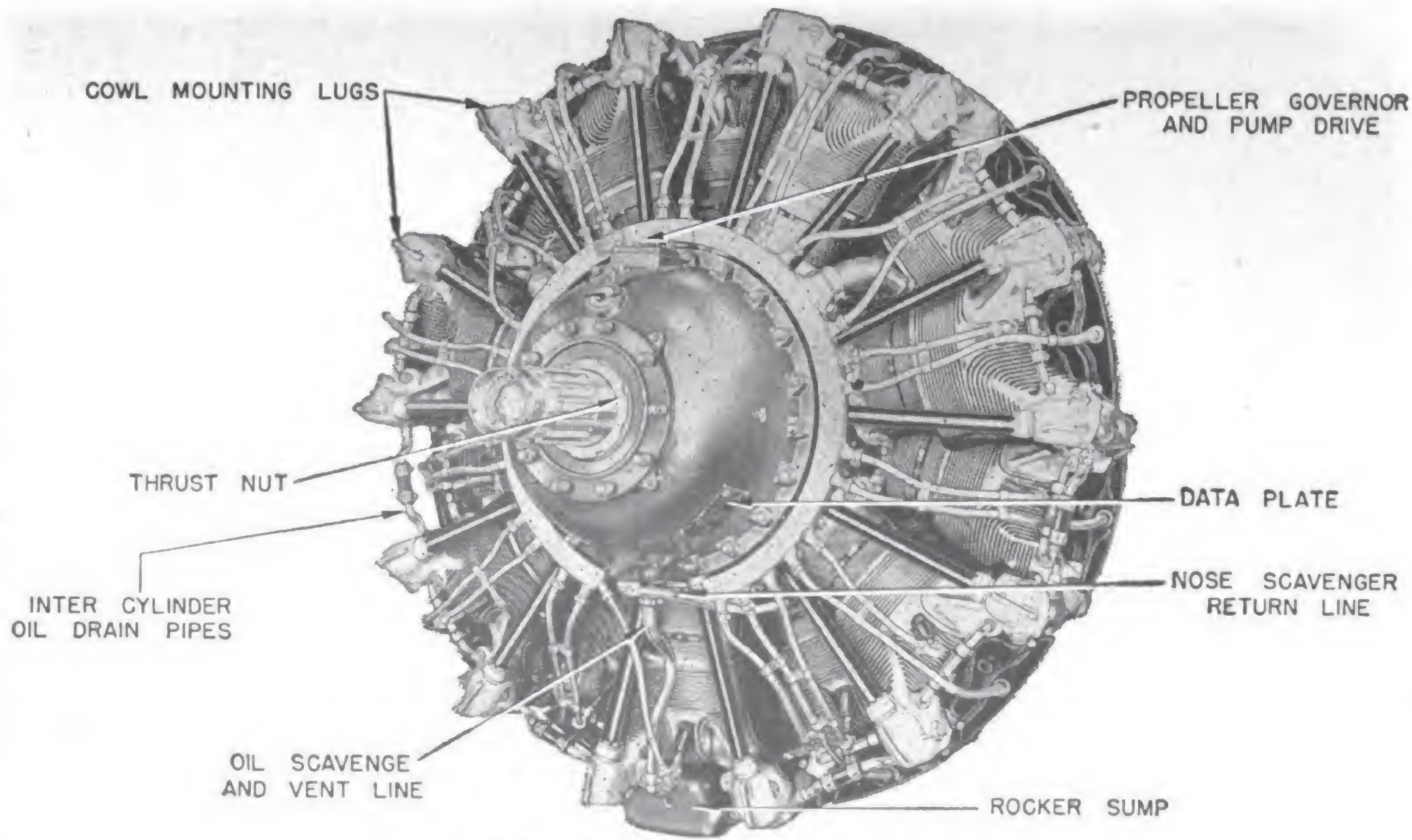
stand the rigors of long-range flights under trying weather conditions, and it has done so.

ENGINE PARTS

The CRANKSHAFT has its main support in three roller bearings which are mounted in the front, center and rear main crankcases. The weights of reciprocating and rotating parts connected to the crankpin are counterbalanced by weights riveted to the outer cheeks of the crankshaft. The MASTER RODS are of the two-piece type.

The CYLINDERS on the R–1830–92 are of steel-and-aluminum construction, as you have learned most cylinders are. The cylinder barrels are machined from steel forgings and have cooling fins. Each cylinder has one inlet and one exhaust valve. Fins of extreme depth are concentrated on the top and exhaust side of the hemispherical (half sphere) head and around the exhaust port. You know the reason for this—the greatest heat dissipation is required at these points. Only shallow fins are required on the intake side. The two spark plugs are nearer vertical than horizontal and are readily accessible—for which you'll be very glad when you have to remove or adjust them.

The VALVES are operated by two single-piece cam rings having external lobes. The front cam is driven through a cam reduction gear by a cam drive gear splined to the crankshaft. The rear cam is driven by the rear crankshaft gear, through a cam reduction gear at the front of the starter shaft. All valve operating parts are enclosed. The tappets actuate the rocker arms through tubular push rods. These rods are, in turn, enclosed by removable oil-tight cover tubes. Two concentric valve springs are used. They are secured to the valve stem by a split cone and



Front view of the Pratt and Whitney Twin Wasp R–1830.

washer. The exhaust valve is of hollow head and stem design and is sodium cooled. The entire valve mechanism is pressure lubricated.

The propeller REDUCTION GEAR RATIO is 16:9. It is of the bevel planetary type. The driving gear meshes with six bevel-type pinion gears which mesh with a fixed gear, splined to a bracket on the reduction-gear housing.

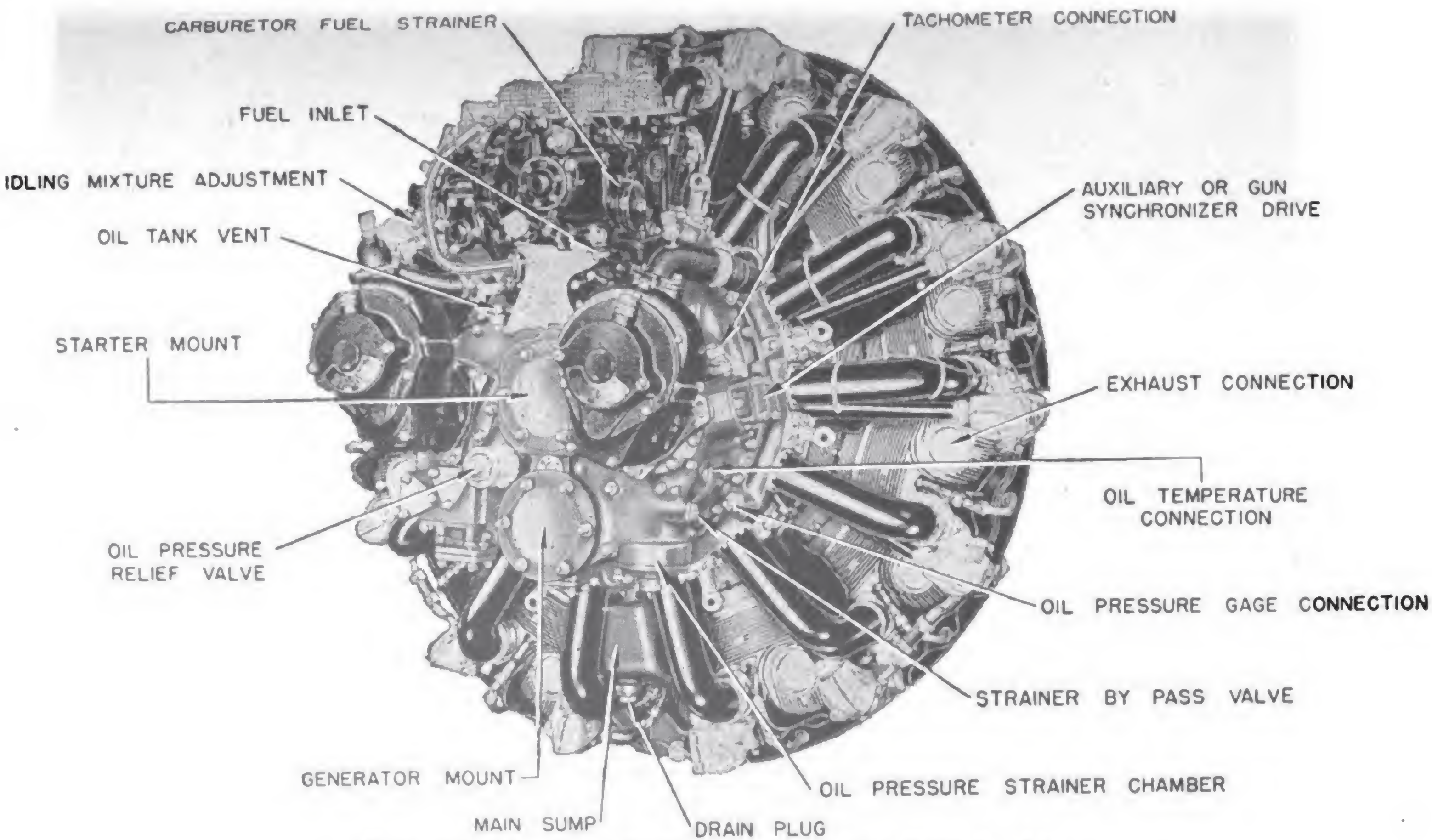
CARBURETOR

This engine is equipped with a PD1Z H-1 Stromberg Injection CARBURETOR and meters fuel in proportion to the mass flow of air to the engine. This type of carburetor has no vented float chamber but consists of a closed fuel system from fuel pump to discharge nozzle.

The throttle unit has two barrels, each barrel having a throttle valve, a large venturi, a boost venturi and a group of impact tubes around the top of the large venturi. Here's an over-all picture of how this carburetor operates.

The throttle valve controls the amount of air entering the engine. The pressure difference between the impact tubes and boost venturi throat is a measure of the volume of air entering the engine. This pressure difference, when corrected by the automatic mixture-control unit for changes of air density, becomes a measure of the mass air flow and is applied to the regulator unit to control the metering pressure across the fixed jets in the fuel control unit. A bypass valve for the automatic mixture-control unit is incorporated in the throttle unit.

The automatic mixture-control unit, mounted on the throttle unit, regulates the differential pressure applied to the regulator unit according to the density of the air. The regulator unit causes the fuel to be metered in propor-



Right rear view of the Pratt and Whitney Twin Wasp R–1830.

tion to the mass flow through the throttle unit. The fuel control unit contains metering jets, an idle valve, a power enrichment valve, and a four-position mixture-control selector valve.

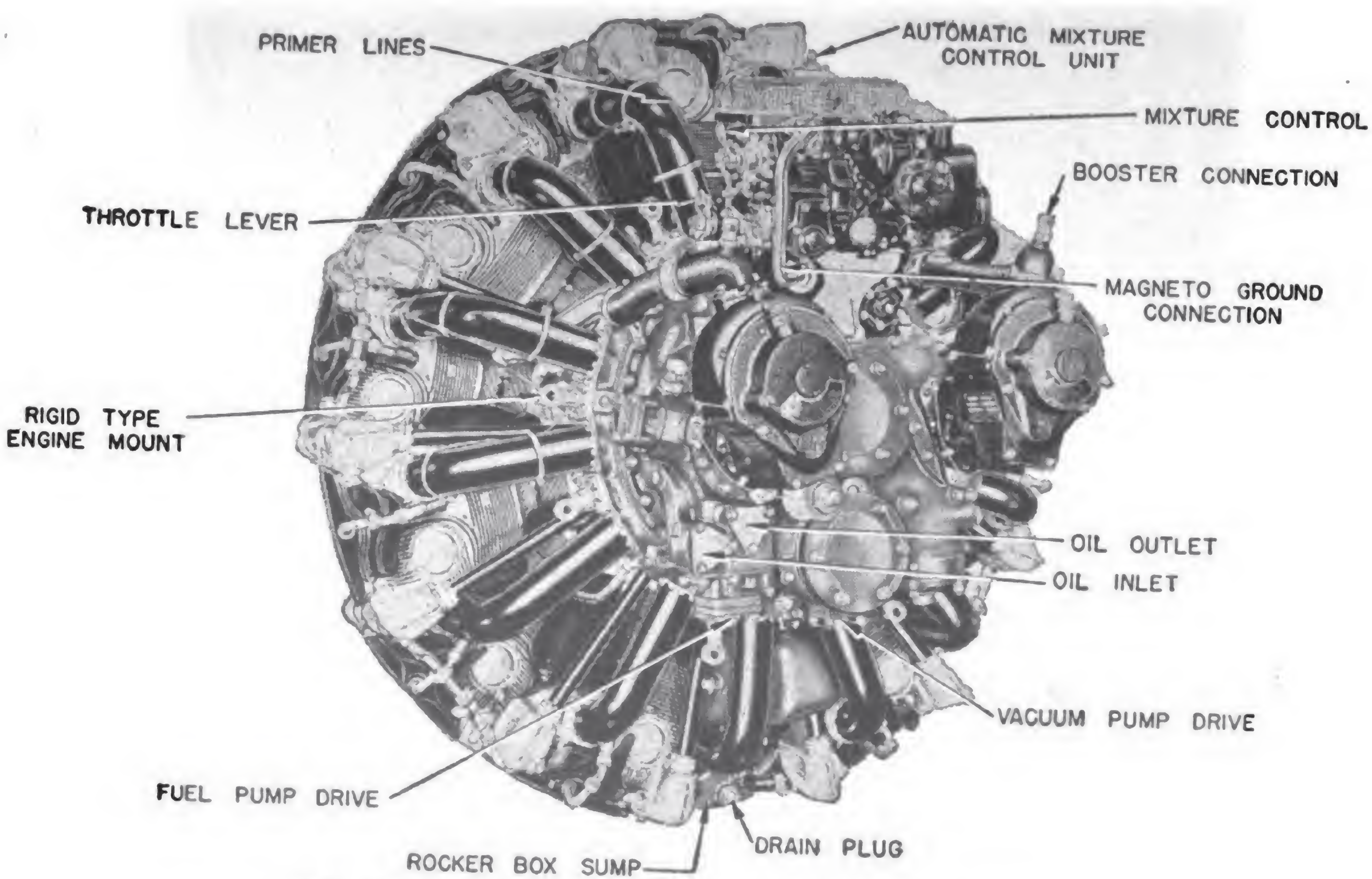
The accelerating pump is operated by the momentary changes in air pressure in the supercharger entrance and is not connected with the throttle or throttle controls. Hence, when the engine is not running, fuel is not pumped from the carburetor even if the throttle is moved rapidly. The metered fuel from the fuel-control unit is delivered to the entering air stream through a spring-loaded discharge nozzle in the carburetor adapter, not through a jet in the venturi as in a float-type carburetor.

IGNITION

The ignition is furnished by either two Scintilla or two American Bosch magnetos located at the rear of the engine, each firing one of two spark plugs in each of the 14 cylinders. Thus, as you can see, there are 2 independent sources of ignition. The right magneto fires the front spark plug and the left magneto fires the rear spark plug in each cylinder. The ignition harness and spark plugs are of shielded types to prevent radio interference.

LUBRICATION SYSTEM

This engine, as you'd expect, is the dry sump type. The oil is circulated through the engine by means of two pump assemblies which consist of one pressure and four scavenging sections. The main oil pump assembly, which combines the pressure section and two scavenging sections, is located at the lower left of the engine's rear section. Another unit in the front or nose section combines the other two scavenging sections.



Left rear view of the Pratt and Whitney Twin Wasp R–1830.

When the oil emerges from the check valve in the oil screen assembly it is diverted through two main branches. The flow of oil is rather complicated to describe in a few words, so you'd better examine a lubrication chart for this engine as soon as you begin to work on it.

The complete system includes—An automatic oil temperature regulator and cooler with a pressure by-pass control, a liquidometer type quantity gage; a sounding rod; and a pressure and temperature gage.

Drain oil from the valve operating parts in the rocker housings is diverted to a small sump installed on the No. 8 cylinder head. Oil draining into the rocker sump and the bottom of the front section is scavenged by the front oil pump. Oil discharged from moving parts within the main crankcase and rear cam compartment drains through separate pipes to the main oil sump located between Nos. 7 and 9 cylinders and is scavenged by the middle section of the main oil pump.

VARIATIONS—TWIN WASP R–1830–86, 88

The giant of the Navy's airforce is the Consolidated PB2Y–2 or "Coronado." This is a flying boat, powered by four, 14-cylinder Twin Wasp, R–1830–88 engines and is designed for use as a patrol bomber. The Grumman Wildcat Fighter (F4F), which was probably the best carrier-based fighter before the Corsair (F4U), is also powered by a Twin Wasp engine of the R–1830–86 model. The two models are similar except for reduction gear and decoupled propeller drive. The R–1830–86 has a reduction gear ratio of 3:2, while the R–1830–88 has a ratio of 16:9 and a decoupled propeller drive.

Both of these engines are later developments

of, the 1830, but they have two-stage, two-speed superchargers for high-altitude performance. The principal differences are the addition of an auxiliary-stage blower section, a redesigned intermediate rear section, and the location of the magnetos on the reduction gear housing at the front of the engine rather than at the rear. The auxiliary-stage blower section houses an auxiliary-stage impeller and drive. The design of the intermediate rear section provides for the accommodation of two dual sets of oil operated clutches for driving the auxiliary supercharger at two different ratios. A selector valve is mounted on the intermediate rear section and is used to direct oil to the respective clutches which disengage the auxiliary-stage impeller or engage the high-ratio or low-ratio gears as desired.

The operating characteristics of the engine, with the auxiliary supercharger in "Neutral," are similar to those of an engine with a single-speed supercharger.

INSPECTION

On your AFTER FLIGHT INSPECTION you should make checks similar to those suggested for the R-1820 engine on the SBD-3. Before you O. K. the engines of the PBY-5 for take-off, however, you should make AN ADDITIONAL PREFLIGHT INSPECTION. The first thing to do is to see that both ignition switches are OFF. Then you can work around the propellers and engines in safety.

See that the ignition terminals are secure. The terminal nuts should be only slightly more than finger tight. See that the ignition ground wires are secure. Make sure the throttle, mixture, and spark controls are free throughout their entire range of operation.

Examine the outside of the engines carefully

for loose nuts or abnormal conditions. Check fuel and oil lines for leaks. Airplane fuel has a BLUE DYE in it, which makes it quite easy to find leaks. Be certain both fuel and oil supplies are sufficient. You can check the fuel supply in the flight engineer's seat. Because of the accuracy of the sight gages, there is no need to check the fuel supply by "sticking the tanks." The oil tanks are 76 gallon capacity—65 of oil, 11 of foaming space. Fuel tank vent openings should be kept open and checked during every preflight inspection. Check the propeller for pits, cracks, and nicks.

The cowl flaps get a lot of vibration when the engines are running. As a result of this constant jarring, the cowl-flap hinge bolts often crack and break. Check the hinge bolts in back of the cowl flaps during every preflight inspection. Look for signs of cracks around the engine cowling and ring cowling. Also, see that this cowling is secure.

A safety discharge line leads from the fire extinguisher bottle to an indicator disk under the right wing near the strut. Check the disk. It should show red, indicating that the CO_2 fire extinguisher bottle is charged.

Remember, your O. K. should say—AND MEAN—"THIS ENGINE IS READY FOR FLIGHT."

STARTING

The PBY–5 has a two-cylinder air-cooled auxiliary power plant. This engine, developing 15 horsepower, drives a 24-volt a–c generator. For electric starting of the main engine, you must have this engine running. This reduces the load on the airplane batteries.

Here's a way to start the auxiliary power plant—

Turn the fuel to ON. This valve is on the right

side of the flight engineer's panel up in the tower. Close the battery switch on the main distribution panel. This panel is on the front side of bulkhead No. 4. Be sure the auxiliary generator switch is ON. Turn the toggle switch on the auxiliary power plant instrument panel to START. This panel is at the left of the power plant. As soon as pressure shows on the oil pressure gage, snap on the magneto switches. When the oil temperature is below 40° C. turn on the oil heater immediately after starting the engine. Turn off the oil heater as soon as the temperature rises to 40° C. As soon as the engine starts, check the oil pressure gage. The normal oil pressure is 55 to 60 pounds per square inch. Warm up the auxiliary power plant until the cylinder head temperature gage reaches 100° C. and the oil temperature is 40° C. Then turn on the auxiliary generator switch on the main distribution panel. After the auxiliary power plant is warmed up, you are ready to start the engine.

From this point on, the job of starting the engine of this airplane is one that demands the cooperation of the flight engineer and the pilot. You are serving as flight engineer. Make sure the pilot has both ignition switches off. Then have two mechanics of the ground crew turn both propellers over at least twice. If the engines have been running within the last hour, this step isn't necessary. As a safety measure when starting the engines have a mechanic stand by, topside on the wing, with a fire extinguisher. At this point the radioman should connect the visual-signal system and the interphone system. Then the pilot sets the interphone control switch to position No. 4. Next the pilot should push the propeller controls all the way forward to set the propeller in low pitch (high rpm.). The pilot signals you over

the interphone system to prepare to start the right or left engine.

You set the mixture control to idle CUT-OFF position. Set the cowl flaps to FULL OPEN position. Turn the cowl flap crank clockwise as far as it will go. Open the fuel valve to BOTH. This connects both fuel tanks to the engine. At this point the pilot sets the throttle at 1,000 to 1,200 rpm position. Then you give the carburetor air control a half turn clockwise. Push it all the way in to set it in DIRECT position. Give the handle a hard turn counterclockwise to lock. Prime the engine with a hand primer pump. Give it three to five strokes (depending on the outside air temperature). Then raise the fuel pressure to about 10 to 16 psi with the wobble pump. Signal the pilot for "contact." Use the interphone system.

After the pilot gets the "contact" signal from you, he turns the ignition switch to BOTH on the engine that is being started. Then he repeats "contact" to you. You start (energize) the starter for not more than 15 seconds. Then mesh (engage) the starter. As soon as the engine starts firing, shift the mixture control to AUTOMATIC RICH. Keep the fuel pressure at 10 to 16 pounds with the wobble pump. If the engine stops, bring the mixture control back to idle cut-off position. Notify the pilot when the oil pressure is up. If it is not up in 30 seconds, however, shut off the engine.

You can also start this engine by hand. Here's the way to do it—

Remove the starter crank handle from its stowed position in the flight engineer's compartment (backside of bulkhead No. 4). Open the bayonet slot door on top of the engine nacelle. Put the crank into the bayonet slot. Turn over the starter by cranking in a CLOCKWISE direction.

After the starter has enough momentum, take out the crank. Snap the safety cable to some part of the airplane and lay the crank down. After the crank is out and the ignition switch has been turned on, pull the engaging rod. Have your helper hold the starter switch on MESH so the booster coil will operate. After one engine is running, start the other engine in the same way.

WARM UP

Keep cowl flaps OPEN for all ground running. Idle the engines at 800 rpm until the oil pressure rises. If it isn't up within 30 seconds, shut down the engine and investigate the oil system and gages. When the oil and fuel gages indicate sufficient pressure, advance the throttle to obtain about 1,000 rpm.

When the oil temperature has reached 25° C., open the throttle so that you get about 30 inches of Hg manifold pressure with the propeller control in high rpm position. Check oil pressure and oil temperature with the propeller control in the take-off rpm position.

Open the throttle to obtain 1,785 rpm and note the loss in revolutions when switching to one magneto at a time. The normal drop-off, in switching from both engines to one, is given in the engine log book. An increase of 50 percent above this is excessive. The oil pressure will vary with rpm and may fall as low as 15 psi with engine idling.

Check auxiliary-stage supercharger control according to directions in the Pilot's Handbook. Check fuel presure to see that it is 14 to 16 psi. It may be expected to drop off slightly at speeds below 1,000 rpm. Keep the cowl flaps OPEN for all ground running.

Remember ground-running cooling is insufficient above 1,400 rpm for the cylinder heads or cylinder

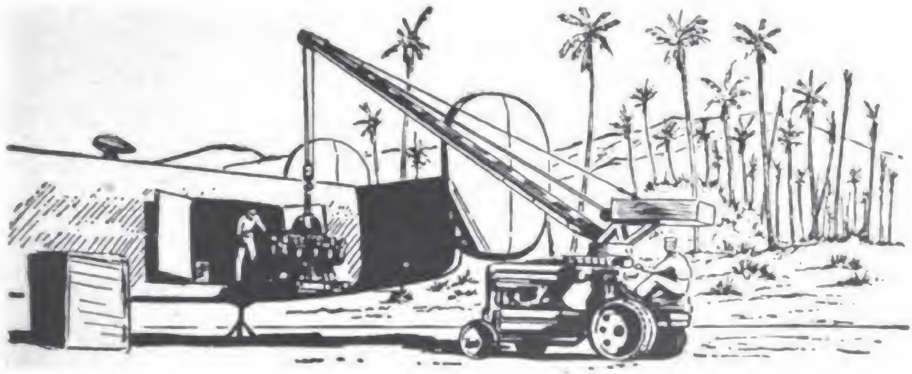
barrels. So avoid prolonged running above 1,400 rpm and keep the head temperature below 205° C. during ground operation. Oil temperature should not exceed 95° C. during the warm-up.

STOPPING

The job of stopping the engines on this airplane is also divided between the pilot and the flight engineer. But if you are coming up to a buoy or beach, you may find it necessary to stop the engines quickly. In this case, simply cut the ignition switches. However, use this method only when you are forced to, or when the regular method is impractical.

Here's the regular way to stop the engine—

As flight engineer, first of all, you open the cowl flaps. The pilot should idle the engine at 1,000 rpm. The engine cylinders should be allowed to cool before stopping. When ready, the pilot should signal you to stop the engines. Set the mixture control to IDLE CUT-OFF position. After the engine stops, the pilot should cut the ignition switches. The fuel cocks should never be shut "OFF" except in emergency or to prevent carburetor drainage and subsequent vapor locks after the engines have stopped. The pilot should signal SECURE on the visual signal system after the airplane is beached or secured to a buoy.



CHAPTER 14

WRIGHT CYCLONE R–2600

WHAT IT IS

The TBF Avenger, because of its high speed and maneuverability, is less vulnerable to enemy antiaircraft and machine-gun fire than its forerunners. In the critical area while approaching an enemy ship, the Avenger's speed enables the use of swift evasive tactics. This modern torpedo bomber, with its complete surprise and killing punch, is one of the leaders in all torpedo operations. It's the type of airplane that knocked out the Jap carriers at Midway, but it's much improved over the old TBD's actually used in that operation.

The TBF–1 Avenger is powered by the sturdy Wright Cyclone R–2600. This engine is a 2-row, 14-cylinder radial. It is air-cooled and single-stage, 2-speed supercharged. Other airplanes using this engine are the SB2A–3, SB2C–1, and TBM–1.

ENGINE PARTS

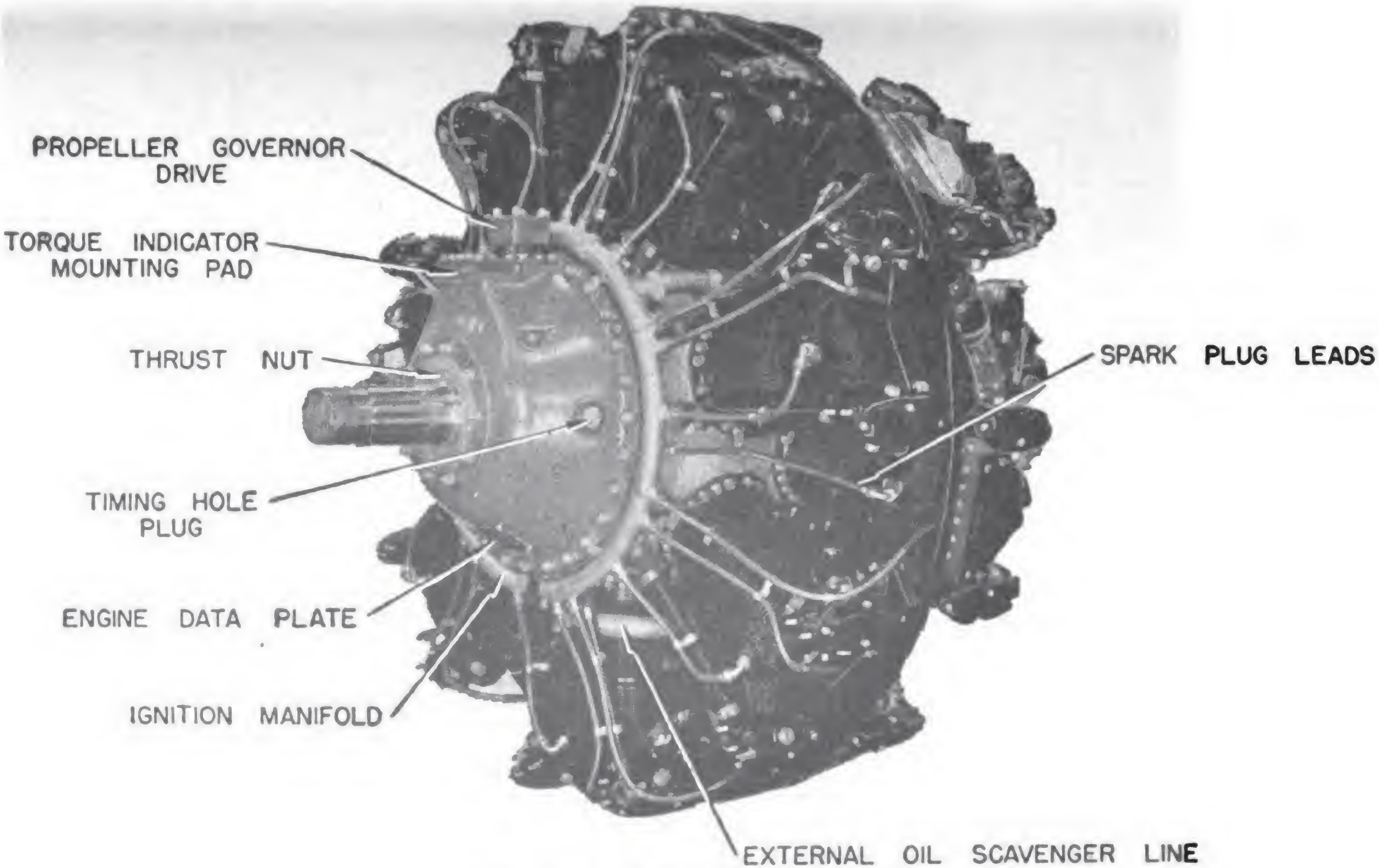
The 14 cylinders are attached to the crankcase in two rows of seven cylinders each. They are staggered to promote cooling efficiency. You'll

also find that this arrangement makes the cylinders much more accessible. The front bank cylinders have exhaust and intake ports at the left and right rear. On the rear bank cylinders you'll find an opposite arrangement—the exhaust on the right and the intake on the left. There is good reason for this construction if you stop to analyze such a set-up. It places two intake and two exhaust ports in alternate groups around the circumference of the engine. This results, you see, in concentration of the exhaust heat away from the intake pipes.

The CYLINDER HEADS are made of cast aluminum alloy, as you've found most cylinder heads are. They have integral cooling fins and rocker boxes. The heads are screwed and shrunk on forged steel cylinder barrels. Intake and exhaust valve seats are shrunk into the dome of each cylinder head. The cylinder barrels, with integral cooling fins, are machined from a Nitralloy steel forging.

The VALVE MECHANISMS, like those you've studied about earlier in this book, are operated by two cam rings. They are mounted on the front and rear main crankcase sections. Each cam is a nickel-steel-alloy forging with three intake and three exhaust lobes on the rim. The cams are rotated at one-sixth crankshaft speed. This is accomplished through gear teeth cut on the inside diameter of the cam ring. These teeth mate with an intermediate cam-drive pinion gear and bring about anticrankshaft rotation of each. The cam lobes acting through the rollers and valve tappets actuate the push rods. These in turn operate the rocker arms which open the valves.

The CRANKSHAFT FRONT SECTION consists of the front crankcheek to which the front dynamic



Front view of the Wright Cyclone R-2600.

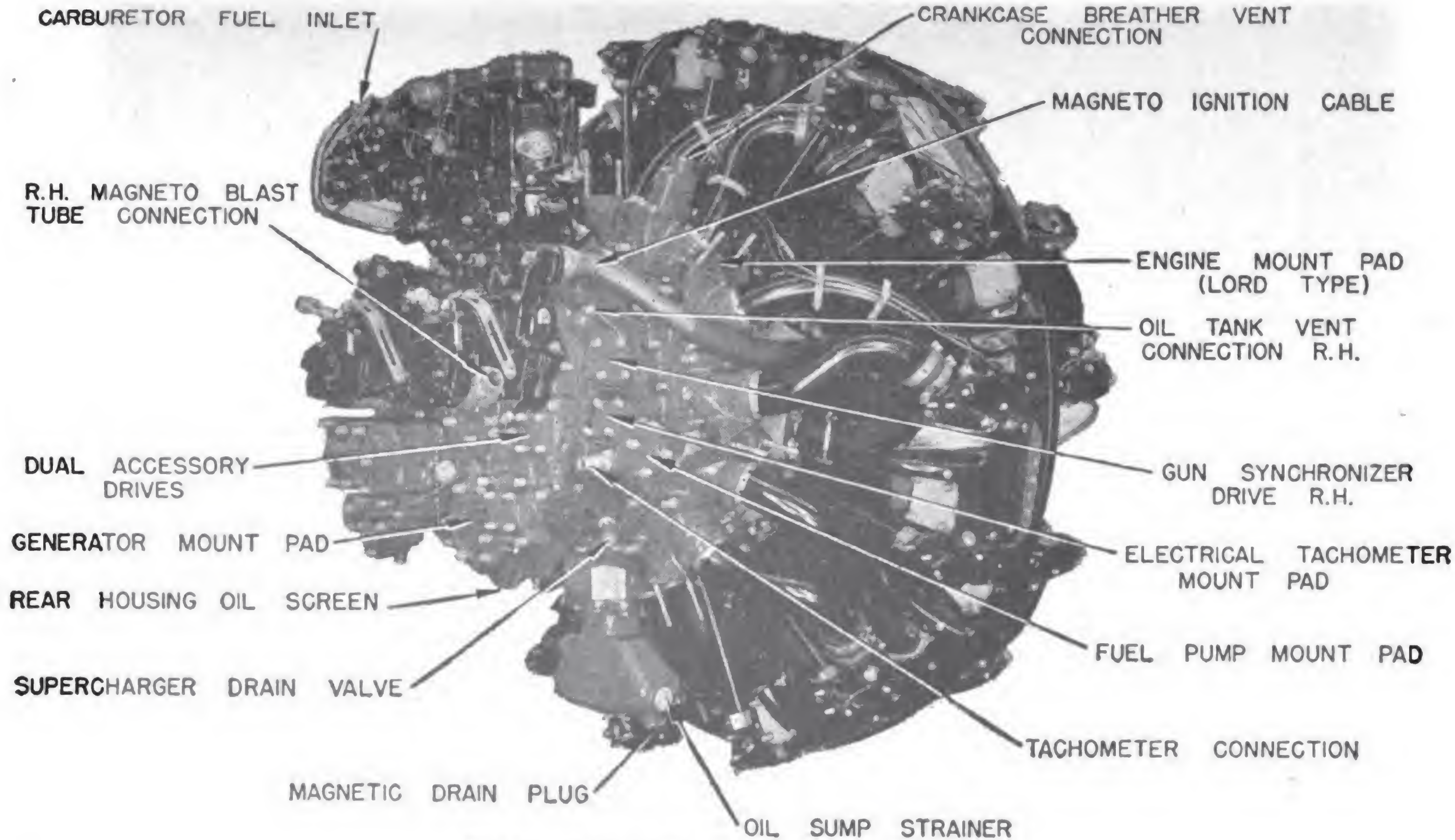
counterweight is attached. This counterweight serves, as you recall, to reduce main bearing loads and vibration. The forward shaft extension, on which are cut the reduction driving gear splines, is also attached to the crankcheek. The propeller shaft is supported on two journals of this shaft extension, and a journal just ahead of the front crankcheek supports the front main roller bearing. The reduction gear parts are all located in the crankcase front section. The ratio of the crankshaft to the propeller shaft is 16:9.

The CRANKSHAFT REAR SECTION consists of a crankcheek, to which the rear dynamic damper is attached, and a rear main-bearing journal with a short hollow-shaft extension. Both front and rear crankshafts are machined from chrome-nickel-molybdenum steel forgings, bored for attachment to the crankshaft center section by means of clamp joints.

A ONE-PIECE MASTER ROD, equipped with six articulated rods, is assembled on each crankpin. You'll recognize that it's the banjo type by its shape. The two master rods are machined from chrome-steel forgings. The pistons are full trunk-type, heat-treated, aluminum-alloy die forgings. A domed head is used to secure the desired compression ratio.

The SUPERCHARGER and all the accessories are driven by a forged nickel steel extension shaft from the rear end of the crankshaft. This is done through an accessory drive gear attached to the shaft. All principal drives are operated through spur gearing located in the supercharger rear cover.

This engine is equipped with a centrifugal-type supercharger, similar in principle to the type you've studied already. The impeller driving mechanism has two plate-type clutches which give



Right rear view of the Wright Cyclone R–2600.

a choice of two impeller speed ratios to the crankshaft.

IGNITION

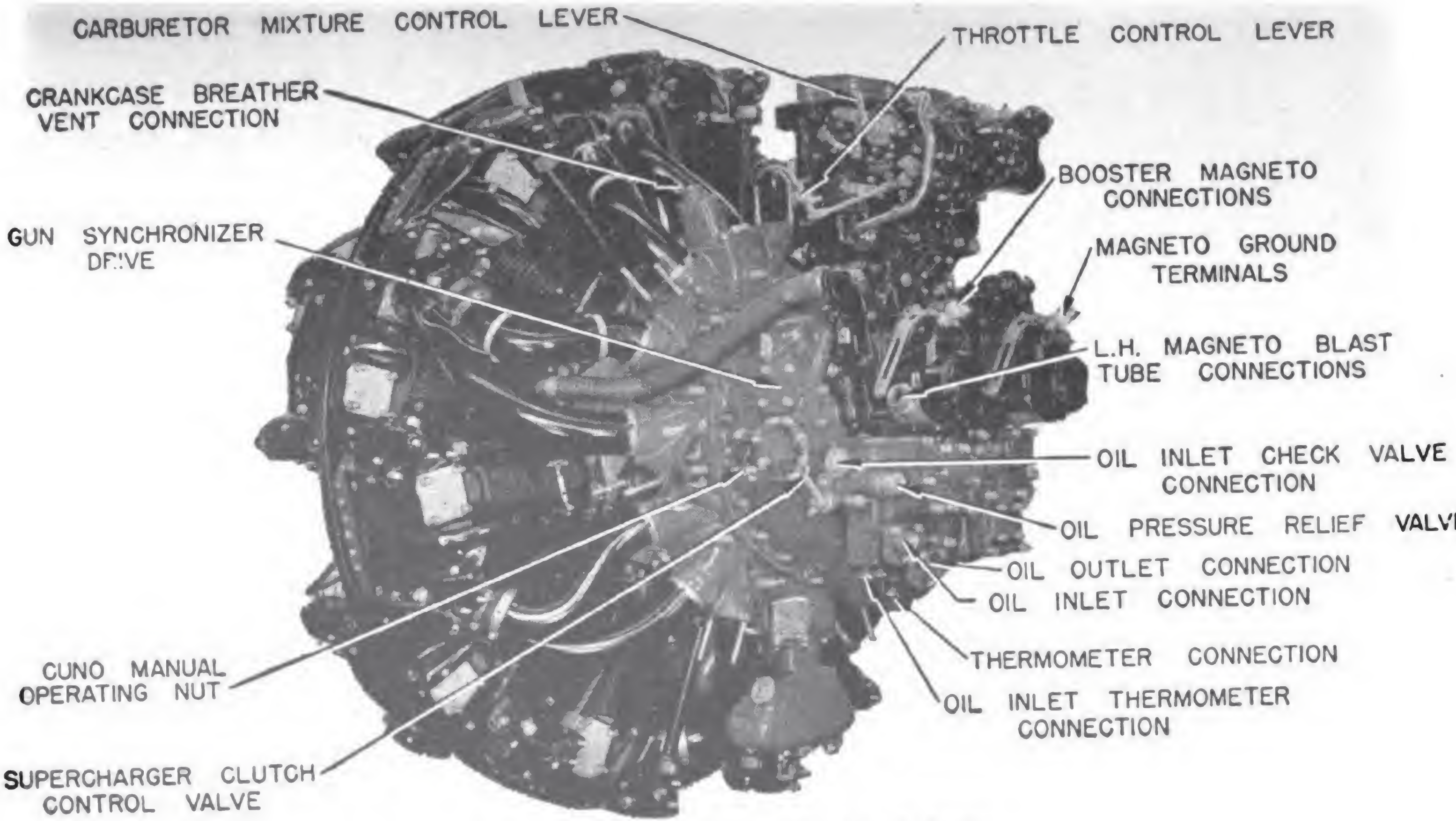
Two Scintilla magnetos attached to the supercharger rear cover supply the ignition. The right-hand magneto fires the front spark plugs and the left-hand magneto fires the rear spark plugs. All parts of the ignition harness assembly are shielded to eliminate radio interference.

CARBURETOR

This engine has a Holley carburetor. The Holley has a single air passage controlled by a variable venturi. You will recall, from an earlier chapter, the effect of the venturi on pressures. In the Holley, fuel is admitted to a supply chamber by a diaphragm mechanism. A controlled pressure differential produced by the variable venturi causes fuel to flow from the supply chamber to the metering nozzle located in the venturi throat. The fuel discharge nozzle and venturi throttles are arranged in such a manner that the carburetor is free of ordinary icing troubles. The accelerating pump on the Holley functions only when the engine is running. Consequently, opening or closing the throttle prior to starting will not flood or prime the engine.

LUBRICATION

You'll need to study the lubrication chart in order to follow the flow of oil through the engine. As you'd expect, however, the lubrication system is the full-pressure dry-sump type. In this, as you know, all moving parts are under oil pressure except the piston rings, piston pins, crankshaft, and the lower valve tappet assemblies. All of these are lubricated by splash



Left rear view of the Wright Cyclone R–2600.

and oil issuing from drilled jets in the crankpins. Oil is drawn from and returned to an external supply tank by an oil pump mounted on the lower left-hand side of the supercharger rear cover.

All of the oil in the engine's lubrication system drains to a sump attached to the bottom of the crankcase behind the No. 8 cylinder. The oil being removed from the sump passes eventually into a drilled passage in the supercharger rear-housing cover. This passage connects with the bottom drilled hole in the engine oil pump. The oil is discharged, at the bottom of the scavenge pump gears, into a cored pocket at the right hand side of the pump. From the cored pocket the oil is conducted by the airplane outlet oil line to the oil supply tank.

INSPECTION

AFTER FLIGHT you should make the routine checks on this engine similar to those suggested for the other engines. On your PRE-FLIGHT inspection you should first make sure the switch is OFF.

The main fuel line strainer is located on the left forward side of the bomb bay and should be cleaned. Before you remove it, make sure that the fuel tank selector valve in the cockpit is OFF also. Then remove the safety. Loosen the wing nut and swinging arm, and remove the cover and strainer. Wash the strainer in clean kerosene and blow it with compressed air. Inspect it for cracks or signs of wear. Check the cover gasket for cracks or signs of wear before reassembling the strainer. Reassemble the strainer and replace the cover. Do NOT SAFETY YET. Now turn the fuel tank selector valve to one of the fuel tanks. Turn the strainer drain valve on for a moment.

This gets rid of air pockets in the fuel system. Turn on the battery switch. Now turn on the emergency fuel pump switch until the fuel pressure gage shows 6–7 psi. While the fuel system is under pressure, inspect the strainer for any sign of leaks, and the fuel lines for any signs of leakage. After making these inspections, SAFETY the wing nut on the fuel strainer.

Turn off the emergency fuel pump, battery switch, and gasoline valve. Check the fuel supply of all the tanks with a stick. Don't rely on gages alone. Check each tank cap to make sure it is on tight.

See that the high-tension terminals are secured to the spark plugs. See that all spark plugs are tight. Check the wiring to the generator for security. Inspect the magneto ground wire for security of mounting. See that the battery cables are securely attached to the battery. Check the reading of the voltammeter. You do this by turning the battery switch on. Then push the voltammeter lever DOWN. The voltammeter should now show a reading of 24–28 volts.

Check the quantity of oil. Normal oil capacity is 11 gallons. The overload capacity is 17 gallons. During engine warm-up check the engine gage for proper operation.

STARTING

Have the fuel supply of all tanks checked with a measuring stick before every flight. You should also check the supply on the fuel gages. Turn the battery switch ON. Then turn the selector switch to all tanks, and check the fuel in each on the fuel gages. Have the oil supply checked before every flight, too. Be sure the wheels are chocked. The engine of this airplane has an electric or

hand-inertia starter. The hand crank is stowed in the bombardier's compartment, just below the door sill. Wherever possible, use an outside electrical force in starting the engine. This saves the airplane's battery which is a mighty important bit of saving.

Here are the steps for the actual starting of the engine—

First, make sure the ignition switch and all accessory switches are OFF. Set the fuel selector valve to the tank you expect to use in taking off. Then place the mixture control in IDLE CUT-OFF position. This control has three positions—RICH, CRUISING LEAN, and LEAN or IDLE CUT-OFF. Set the cowl and oil cooler flap controls to OPEN. Be sure the switch is OFF! Now have the engine pulled through four or five revolutions by hand. Then crack the throttle slightly. It should be set for 600–800 rpm. Operate the emergency fuel pump until there is a pressure of 6 psi. Now prime the engine with the automatic primer. To prime, lift the lever on the right-hand side of the instrument panel. The engine will usually require only a couple of seconds of priming. Set the supercharger control at LOW RATIO. Set the propeller in a low pitch. Push the propeller vernier ALL THE WAY IN. The carburetor air control should normally be on COLD (direct). IF NOT USING OUTSIDE BATTERY SOURCE, TURN THE BATTERY SWITCH ON.

Turn the ignition switch on BOTH. Turn on the starter switch. Energize for 15 seconds—then engage the engine. Now move the mixture control to FULL RICH position. The engine should now start. If it fails to start, or fails to keep running, return the mixture control to IDLE CUT-OFF position.

During warm-up, leave the carburetor air-heat control cowl and oil cooler flaps in the same position as for starting. To prevent damage to the oil pressure gage, avoid high oil pressure when the engine is still cold by holding down the rpm. To warm up the engine, run it at 1,200 rpm until the oil temperature reaches 55° C. In cold weather, if you get excessive oil pressure when the speed is increased to 1,000 rpm, the engine should be operated at 800 rpm until the oil pressure drops below 100 psi. Open the throttle to obtain 30 inches of Hg manifold pressure.

If the oil pressure drops or goes up and down when the throttle is open, reduce the engine speed and continue the warm-up. When the oil pressure steadies out, run the engine up to about 1,800 rpm and check both magnetos. THE ENGINE SHOULD NOT DROP MORE THAN 100 RPM WHEN EITHER MAGNETO IS CUT OUT. Operate on a single magneto for as short a time as possible and return the magneto switch to BOTH after each check to let the engine clear out.

Here's the way to check the two-speed blower—

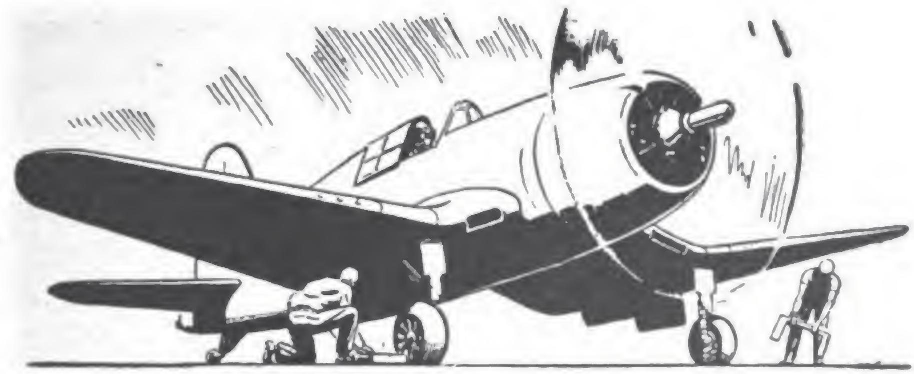
With the propeller set at FULL LOW pitch, close the throttle completely. (On –8 and –8A engines, instead of closing the throttle completely, adjust it for 1,500 rpm.) Then move the blower control rapidly from LOW to HIGH. Open the throttle to get a maximum of 30 inches of Hg. Now shift the blower control to the LOW position without moving the throttle. A sudden drop in manifold pressure is a sign that the two-speed supercharger drive is working right.

Check the fuel selector valve during warm-up by running the engine for a FULL MINUTE ON EACH TANK. After the check, return the selector valve to MAIN TANK. See that the generator is charging.

Check the throttle operation. See that the friction crab is OK, and does not let the throttle back from any set position. Finally, make a radio ground check. Do not turn on ANY electrical accessories unless the engine is turning at least 1,400 rpm. On the ground, do not keep up high-power running that might make the engine too hot. NEVER LET THE CYLINDER HEAD TEMPERATURE GET ABOVE 205° C. UNDER ANY CONDITIONS.

STOPPING

Set the cowl and oil cooler flaps for ground cooling. With controls set as in landing, idle the engine at 800 rpm until the cylinder head temperature drops below 149° C. Shift into high blower for 30 seconds. Then increase the engine rpm to 1,000—hold for one-half minute and move the mixture control to IDLE CUT-OFF position. When the engine cuts out, advance the throttle to FULL OPEN. The engine will stop in a few seconds. Turn off all accessory switches. Then turn the ignition and battery switches to OFF. Turn the fuel selector valve to OFF.



CHAPTER 15

PRATT AND WHITNEY DOUBLE WASP R–2800

WHAT IT IS

CONTROL OF THE AIR.—That's the vital and determining factor in the majority of land and sea actions. But to maintain control of the air once attained, you have to have planes that will shoot down anything the enemy sends over. That's the job of the fighter.

The fighter is the specialist of military aviation. Yet it carries no torpedoes, seldom carries bombs, and is not suited for long-range reconnaissance. Its job is TO KNOCK DOWN ENEMY AIRCRAFT that come within its range. And that's a tough assignment!

The fighter is able to perform its task because of its maneuverability, its rapid climb rate, its speed and its concentrated fire power. One of the Navy's most effective single-seat fighters is the F4U–2, or Corsair. This airplane is among the fastest and most deadly fighters in the world. It is powered by a 2,000-horsepower, air-cooled, radial engine and bores through the air at better than 400 miles per hour. The engine, a Double Wasp, Pratt and Whitney R–2800–8, is a further

development of the twin-row engine such as the R–1830–92 or R–1830–88 previously described. It has two rows of nine cylinders, with a piston displacement of 2,800 cubic inches, is two-stage, two-speed supercharged and weighs 2,428 pounds.

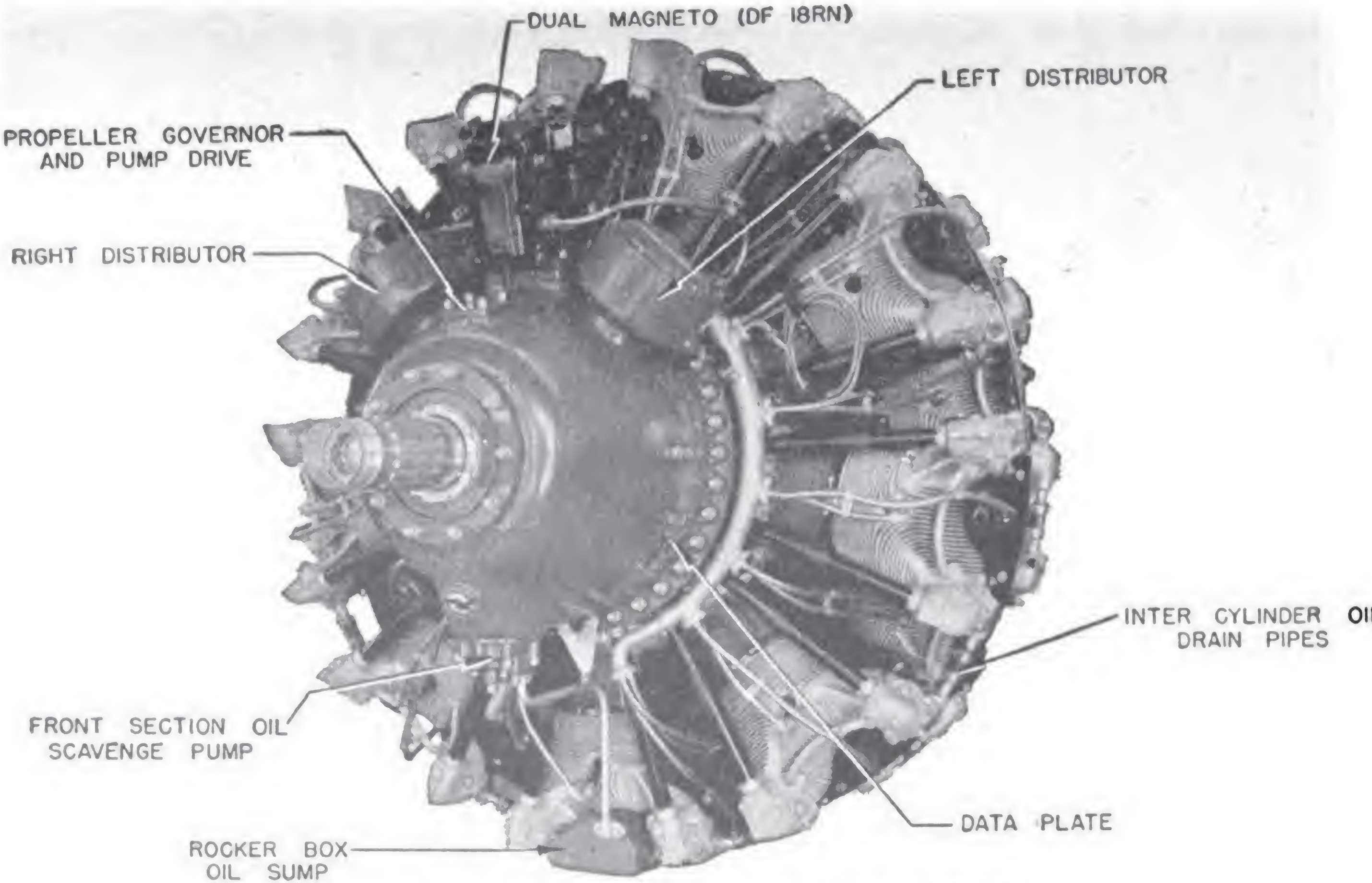
The principal feature which will distinguish it for you from the Twin Wasp engine with single-stage supercharging is the design of the accessory section. This incorporates two blower units (main and auxiliary) together with their driving mechanism. The main stage blower turns at a fixed ratio to engine crankshaft speed. But the auxiliary stage blower can be disengaged (neutral) from the crankshaft or geared through hydraulically operated clutches (cone type) to either LOW or HIGH RATIO. The shift is made by means of a manual selector valve which controls the oil-operated clutches.

You remember that the impeller in a supercharger runs much faster than the crankshaft. The capacity of a centrifugal compressor, moreover, depends upon its speed. Accordingly, at high altitudes a shift to a higher ratio greatly increases the quantity of air going into the engine. The auxiliary stage blower is thus able to supply air at sea level pressure to the carburetor, even though the plane is at an extremely high altitude.

If you're high up in the blue, the ability to make this shift to a higher degree of supercharging is vital. You can imagine how much it means to a pilot when he's tangling with a Zero 4 miles above his carrier base. Improved high altitude performance, resulting from two-stage supercharging, may then be the margin between life and death.

ENGINE PARTS

The CYLINDERS and VALVE MECHANISMS are, in general, similar in construction and operation to



Front view of the Pratt and Whitney Double Wasp R–2800.

those of the Twin Wasp R–1830–92 and R–1830–88. Cylinder baffles, between the rocker housing on each cylinder head and between adjacent cylinders, force a high velocity flow of cooling air through and around the finning on both rows of cylinders.

The CRANKSHAFT is machined from three steel forgings having two throws which divide at the center of the crankpins where it is splined and bolted together. The crankshaft assembly is supported by steel-backed bronze bearings mounted in the front, center, and rear main crankcase sections.

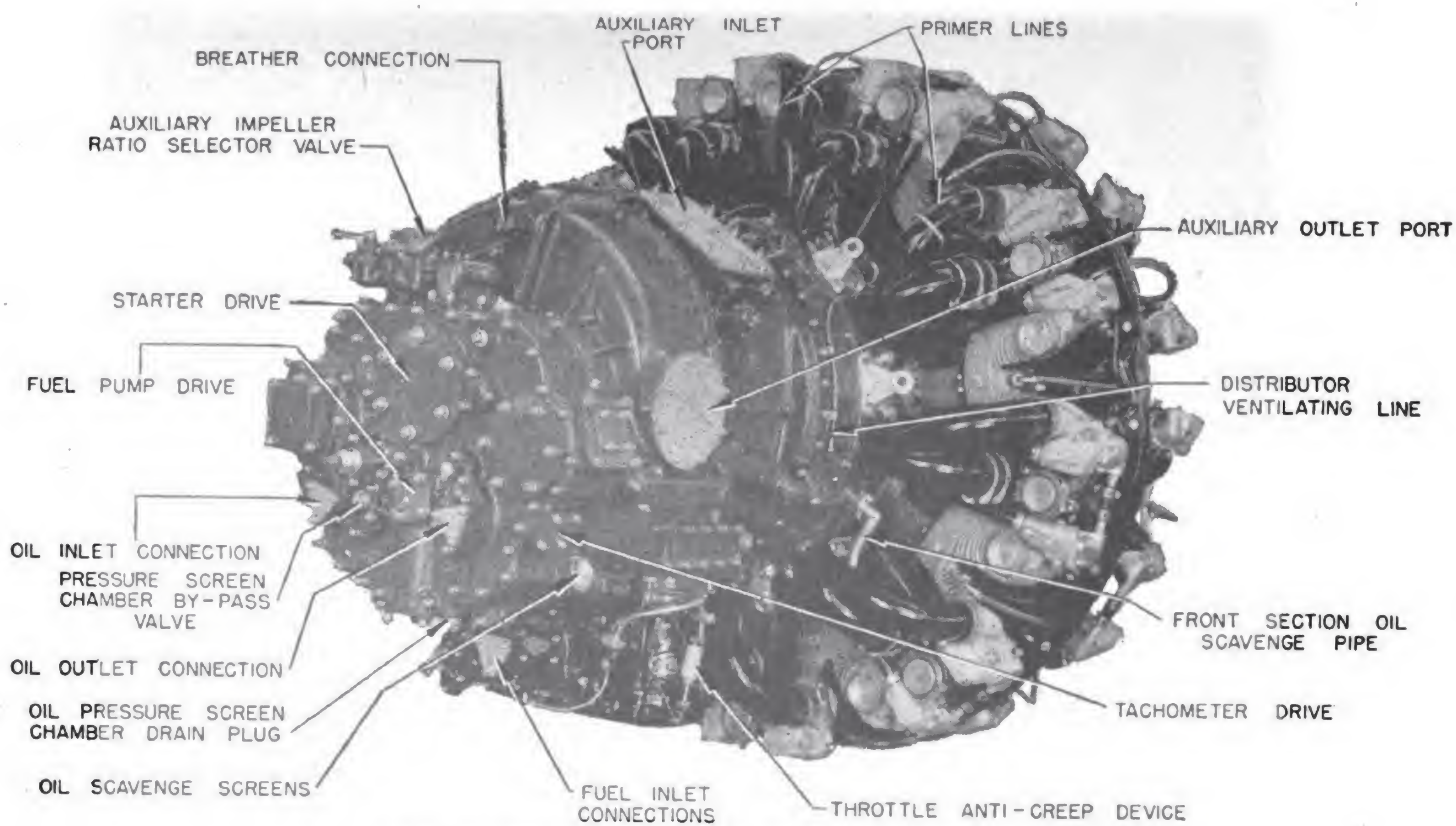
The weights of the reciprocating and rotating parts connected to the crankpin are COUNTERBALANCED BY WEIGHTS riveted to the outer cheeks of the crankshaft. The real counterweight incorporates two removable torsional vibration dampers.

On this engine you'll also find secondary counterbalances provided at each end of the crankshaft. These dampen the second-order vibrations caused by the master rod assemblies, and other undersirable vibrations not balanced by conventional crankshaft counterweights. The counterbalances turn on sleeve bearings mounted on the crankshaft and are driven at twice crankshaft speed by spring drive gears attached to the crankshaft through intermediate gears mounted on the support plates.

This engine has a 0.500:1 propeller REDUCTION GEAR RATIO. The gear is of the compound spur planetary type.

CARBURETOR

Cold air, taken through openings or scoops in both wings of the F4U–1, passes through ducts to the auxiliary stage supercharger. The com-



Right rear view of the Pratt and Whitney Double Wasp R–2800.

pressed air leaves the engine through openings on both sides of the engine and passes through ducts to the two INTERCOOLERS. After passing through the intercoolers, the air flows into the carburetor air box and then into the carburetor.

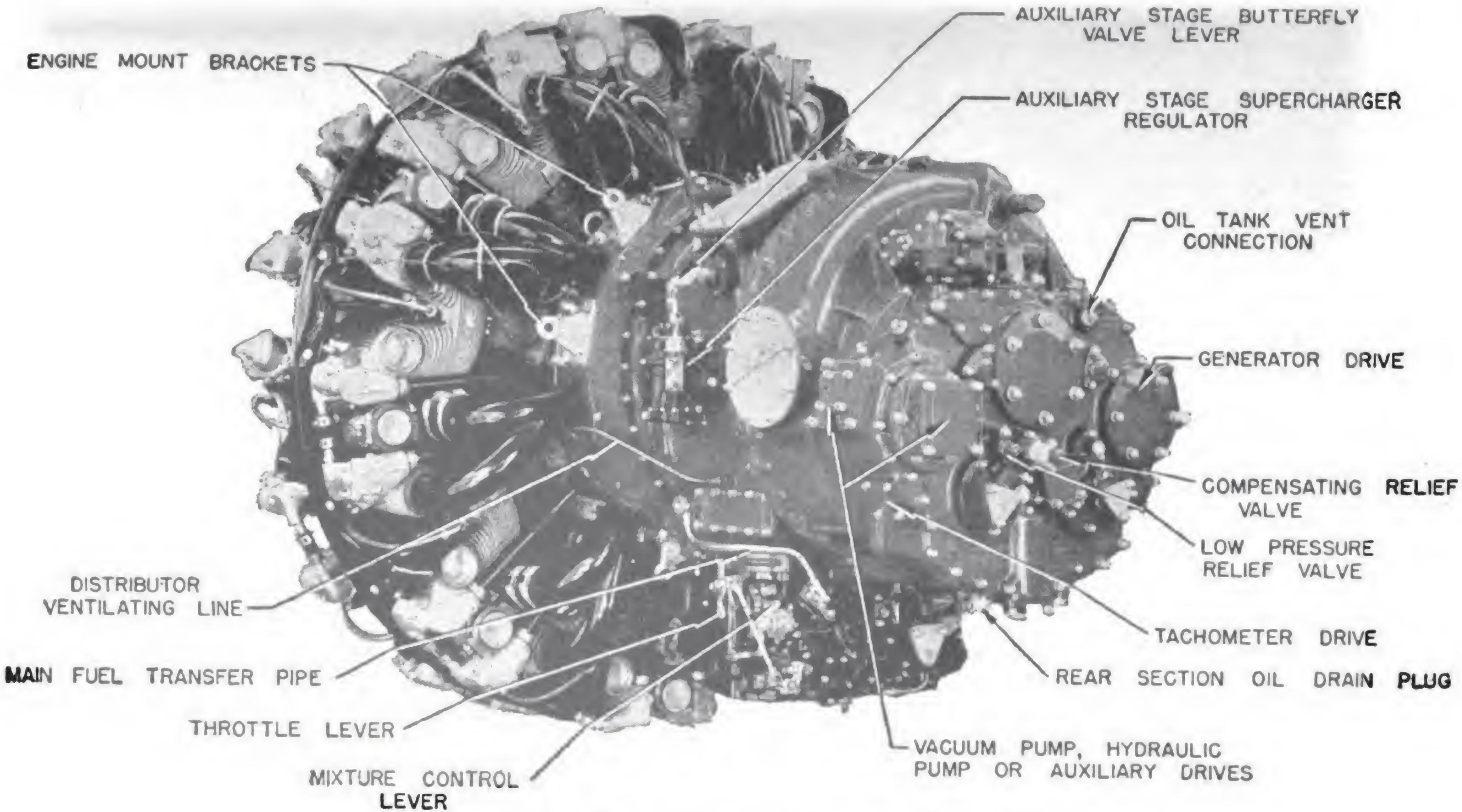
This engine is equipped with a PT–13D4 Stromberg injection carburetor which meters fuel in proportion to the mass flow of air to the engine. The throttle unit has three barrels rather than two, as in the case of the Twin Wasp C–3. Otherwise, it is similar in general construction and operation to the carburetor on a Twin Wasp.

The automatic mixture-control unit is mounted on the throttle unit and vented to the throat of the large venturi. It regulates the differential pressure applied to the regulator unit according to the density of the air. The different pressures produce an air metering force which controls the fuel valve and thereby a corresponding fuel metering force. This force causes a fuel differential pressure across the metering jets in the fuel control unit and the fuel is metered in proportion to the mass air flow through the throttle unit.

The ACCELERATING PUMP is operated by the fuel pressure in the carburetor, and the discharge of fuel is controlled by the operation of the throttle. Hence, when there is fuel pressure, whether the engine is running or not, fuel is momentarily discharged into the engine if the throttle is opened rapidly. This action, you will recall, differs from that of the pump of the Twin Wasp, which is not connected with the throttle or throttle controls. In that engine, no fuel is pumped from the carburetor if the throttle is moved, no matter how rapidly.

IGNITION

The ignition is furnished by a duel Scintilla magneto and two distributors separately mounted



Left rear view of the Pratt and Whitney Double Wasp R–2800.

on the front (nose) section. The magneto has two contact breaker assemblies. The left distributor supplies current to the rear spark plugs. The two distributors and the ignition harness form a completely shielded unit to carry the current to the shielded spark plugs. The distributors are provided with a vent and drain system to prevent an accumulation of moisture which might impair their operation. Later types have a cast magnesium harness and the distributors are equipped with rotor-pumps for high altitude flying.

LUBRICATION

Oil from the tanks is circulated through the engine by a gear-type pressure pump which is situated in the left rear face of the rear section. The oil, after passing through the pressure pump, flows to the oil-pressure screen chamber. This chamber, located in the central portion of the rear section, has two cylindrical oil screens with a check valve at the top. The check valve prevents the oil in the main tank from flowing into the engine when the engine is stopped. The oil from the pressure chamber passes through the check valve to a chamber directly above, from which a passage connects with an annulus around a bushing in the center of the rear section.

You will need to study the lubrication chart for this engine very carefully in order to understand the three branches of the oil system. The first branch, which receives oil from the annulus, lubricates the crankpins, master rod bearings, floating knuckle pins, crankshaft main bearings, cylinder walls and piston pins.

The oil for the second branch is taken from the main accessory drive shaft. It lubricates the two main impeller intermediate gears, the valve operating mechanism for the rear row of cylin-

ders and the rear secondary counterbalance intermediate gear.

In the third branch the oil is taken from the propeller shaft, forward of the reduction gear. It lubricates the magneto and distributor-gear train bearings, the front-counterbalance intermediate-gear bearing and the front valve-operating mechanism.

The engine drain oil is scavenged by two separate gear type pumps. The main pump is located in the right rear face of the rear section and the other is in the bottom of the front (nose) section. The drain oil from the power, main blower, auxiliary blower, and intermediate rear sections is collected in the main sump located below the crankcase between cylinders 9 and 11. This sump is scavenged by the main pump. The drain oil from the front cam compartment, from the reduction gearing, and from the rocker drain sump is scavenged by the nose pump.

INSPECTION

You should make a thorough AFTER-FLIGHT inspection of this engine, just as for the other engines described in this book. Before you begin either your after-flight or your preflight check, however, make sure the switch is OFF.

Here are the main steps in a thorough PRE-FLIGHT inspection—

Inspect the propeller blades for cracks, nicks, and pits. Take off the engine cowling. Inspect each piece for cracks. Check the cowl flaps. Make sure the snap fasteners are secure. Inspect the exhaust stacks. Look for cracks in the pipes. Make sure they are securely attached. Check the rocker box fittings. See that the caps are securely in place. If there is a sign of leakage, change the cap.

Check the spark plug terminal assemblies, their cleanliness and tightness. Inspect all ignition wiring. Check to see that the harness is mounted securely.

Clean the main fuel line strainer. To do this, reach through the intercooler flap opening and cut the two lock wires. Turn the petcock handle up and drain out a small mount of fuel. Inspect the sample for any water or dirt. If you find any, REPORT it to a superior. Take out the strainer screen. Flush it or clean the mesh with an air hose. Put back the strainer and fasten it securely in position. Close the petcock and safety it to the handle of the strainer.

Look for leaks in the fuel and oil lines. Oil lines have a YELLOW band on each side of every side of every connection. Fuel lines have a RED band. Check the security of the oil drain plugs. Check the supply of fluid in the hydraulic system reservoir. Use the stick gage attached to the tank cap. Put back the engine cowling. Be sure that each piece is securely in place. Use a stick in the main tank and the two outer panel tanks to get a reading on the fuel load. Be sure to put the cover back on tightly. Also check the tank vents to be sure they are open. Take an oil supply reading with the sounding rod attached to the tank cap. Put back the cover and tighten it.

STARTING THE ENGINE

Now let's prepare to start the engine. See that the wheels are chocked. Make sure there is a fire extinguisher handy. BE SURE THE IGNITION SWITCH IS OFF. Be certain the starter switch is OFF. When the cover is down, the switch must be in the OFF position.

Check the fuel quantity on the electric gage at the lower right on the instrument panel. To do

this, turn on the main battery switch and the instrument switch. Be sure to turn them OFF after checking. Let your helper pull the propeller through four or five revolutions to clear the lower cylinders of oil or gasoline. Open the cowl flaps. Use the hand pump at the left of the seat to work up enough hydraulic pressure to open the cowl flaps. The cowl flap control handle is spring-loaded. Hold it in the forward position until the flaps are fully opened. The handle will spring back to neutral.

Turn the fuel selector valve to RESERVE. Place the propeller control full down for maximum rpm.

Push the alternate air control full in to the direct position. Alternate air supply is used only when icing conditions exist. NEVER use alternate air (control full out) for starting, or a backfire will blow directly into the engine compartment. Set the supercharger control at NEUTRAL. Set the mix control in the IDLE-CUT-OFF position. Open the throttle about one inch. DO NOT MOVE OR PUMP THE THROTTLE UNTIL THE ENGINE IS RUNNING SMOOTHLY, or excess fuel will discharge into the air ducts, creating a fire hazard.

After these preparations you can start the engine. Check again to be sure all electric switches are OFF. The starter breech should be loaded with the type of cartridge specified for weather conditions. Be sure the starter breech and access door are closed and locked. Turn the battery switch to ON. The instrument switch operates the electric fuel gage, the oil temperature gage, and the remote compass. It must be ON for all airplane and engine operations.

Turn the electric emergency fuel pump switch to ON. Check the pressure for 15 to 17 pounds. To prime the engine intake passages and lower

cylinders, move the mixture control to FULL RICH EMERGENCY and back to IDLE-CUT-OFF. This is a 1-second operation. After a few seconds, see if any fuel drips from the backfire valves or from the blower drain tube. If no fuel drips, repeat the 1-second movement once. Return the mixture control to IDLE-CUT-OFF. If fuel does drip, wait until it stops before firing the cartridge.

For warm starting, hold the electric primer switch ON for about 4 seconds. For cold starting hold the switch ON for about 7 seconds. Then release it. Turn the electric fuel pump OFF after you have primed the engine.

Get the "All Clear" from your helper. Turn the ignition switch to BOTH. Turn the starter switch to ON in order to fire the cartridge. This switch also controls the ignition booster. Hold it ON until the engine runs smoothly. When the engine starts on the prime and runs fairly smoothly, ease the mixture control out of IDLE-CUT-OFF to AUTOMATIC RICH. Hold the ignition booster on. If the engine does not pick up speed, move the control back to IDLE-CUT-OFF. When the speed picks up, then move the control to AUTOMATIC RICH. When the engine is running smoothly with the mixture control in AUTOMATIC RICH, control the rpm with the throttle.

Have your helper remove the discharged cartridge and close and lock the breech and the starter access door. IF oil pressure DOES NOT rise to normal in 30 seconds after starting, STOP THE ENGINE IMMEDIATELY and investigate.

Now let's see what to do if the engine does not start. If the cartridge does not fire, there may be a short circuit. Push the circuit breaker and try the starter switch again. If it still fails, DO NOT REMOVE THE CARTRIDGE FROM THE BREECH FOR AT LEAST 5 MINUTES. If the cartridge fires

but the propeller does not turn over, the load on the starter blew open the safety disk or relief valve. If the starter has a safety disk, it must be replaced. If the starter has a relief valve, try another cartridge. If the cartridge fires, but the engine does not start, wait a few minutes to let any spilled fuel drain out of the air intake ducts and to let the cartridge cool off.

Inspection of the exhaust pipe outlets from the upper cylinders should indicate over- or underpriming. Absence of smoke indicates underpriming. Excess black smoke indicates overpriming. These facts should guide you in further use of the electric primer switch. If the engine is flooded, clear the cylinders and induction system of excess fuel. Leave the mixture control in IDLE-CUT-OFF. Turn off the electrical emergency fuel pump. Turn off the ignition switch. Be sure there is no cartridge in the starter breech.

Open the throttle wide, while the mechanics pull the propeller through four or five revolutions. This will clear the cylinders and induction system of excess fuel. Begin the starting procedure again.

CAUTION.—If the engine catches fire, PUT THE FIRE EXTINGUISHER NOZZLE INTO THE AIR INTAKE DUCT in the leading edge of the wing. The CO_2 goes directly into the carburetor.

WARM-UP

The cowl flaps should be wide open for all ground operations. The oil cooler flaps should be closed. The alternate air control should be FULL into DIRECT. Use the alternate air supply only under icing conditions. The mixture control should remain at AUTOMATIC RICH, and the propeller control should be full down to get maximum rpm. Oil pressure should come up to normal within 30 seconds after starting the engines. If it

does not, stop the engine immediately and investigate. When the oil is cold, pressure as high as 330 to 400 pounds may exist. Under these conditions do not exceed 800 rpm until the pressure falls to 200 pounds, the maximum on the gage.

Now let's go through the warming-up procedure. Hold the rpm to 1,000 until the oil temperature exceeds 40° C. and the cylinder temperature is about 120° C. For the ground test, oil temperature should be 40° C. minimum, 60° C. preferred. Cylinder temperatures should be 120° C. minimum. The maximum permissible for all ground operations is 232° C. Increase the rpm to 1,500, but do not exceed that figure except for short periods.

Check the fuel flow for all tanks. Check the engine controls. Slow response means too much play in the system. Pull up the propeller control. Check for a drop in rpm. Return the control to the down position for maximum rpm. For a check of engine operation, open the throttle to 2,000 rpm or at least 30 inches of Hg manifold pressure. Check the magnetos at 2,000 rpm by switching from both to one magneto at a time. The drop should be not more than 100 rpm. Make this check in as short a time as is practical. Check the oil pressure for 70 to 85 pounds. Check the fuel pressure for 15 to 17 pounds.

Note the manifold pressure as a reference for future checks. In other words, learn the performance habits of the airplane. At this point in the warm-up, the manifold pressure should be the same in day-after-day operation. If it is not, check the propeller control setting. If this is correct, there may be a leak in the manifold pressure line. Stop the engine and investigate.

After noting the manifold pressure, open the throttle further to approximately 35 inches of Hg manifold pressure for a flash run. Push the volt-

ammeter button to check the generator output. The generator voltage should be between 28.5 and 29.5 volts.

To check the supercharger control operation, run the engine at 1,200 to 1,400 rpm with the propeller pushed down for maximum rpm. See that the oil temperature is at least 60° C., and that the oil pressure is about 50 pounds. Shift to low blower by moving the supercharger control without hesitation to the LOW position. The oil pressure will drop momentarily and then return to normal. The manifold pressure will fluctuate and then settle down to a slightly higher pressure. The rpm may drop slightly. Allow the control to remain in LOW BLOWER for several seconds to cool the clutches.

Check the engine operation and instruments. Shift to high blower by moving the supercharger control without hesitation to the HIGH position. Again, let the engine run for several seconds. Check normal engine operation and instruments. Shift directly from HIGH TO NEUTRAL BLOWER when the check is completed. THE BLOWER SHOULD BE SHIFTED AT LEAST ONCE A DAY TO PREVENT COLLECTED OIL FROM DAMAGING THE CLUTCHES. If further testing is required, run the engine at approximately 1,000 rpm or less for at least 2 minutes to let the supercharger clutches cool. To AVOID FOULING THE SPARK PLUGS, DO NOT IDLE THE ENGINE BELOW 800 RPM FOR TOO LONG.

STOPPING THE ENGINE

To stop the engine, follow these steps—

Set the throttle to obtain 800 to 1,000 rpm. Leave the cowl flaps wide open to cool the engine while idling. Leave them open for at least 10 minutes after stopping the engine.

Open the intercooler flap to cool the accessory compartment. Open the oil cooler flaps as required. Both the intercooler flap and oil cooler flaps are hydraulically operated. Hold the spring-loaded controls full forward until the desired flap setting is reached. The handles will spring back to neutral. Check the propeller control. It should remain down for maximum rpm. The alternate control stays pushed in for direct supply.

When the cylinder temperatures drop below 200° C., pull the mixture control back to the limit of movement—to IDLE CUT-OFF. Open the throttle wide to clear the cylinders and induction system of the last traces of fuel. When the propeller stops, turn the ignition switch to OFF. Turn the fuel selector valve to OFF. Turn off the battery and instrument switches. Leave the mixture control at IDLE-CUT-OFF at all times when the engine is not running.

How well do you know —

AIRCRAFT ENGINES

QUIZ

CHAPTER 1

ENGINE PRINCIPLES

1. (*a*) If a jeep pulls with a force of 900 pounds in hauling a loaded bomb truck up a hill one-half mile long, how much work does it perform?
   (*b*) If the jeep in (a) is traveling at the rate of 4 mph, how much power does it exert in pulling the load?
2. (*a*) When confined gas is kept at constant temperature, what effect will an increase in the volume of space occupied by the gas have on its pressure?
   (*b*) When gas is confined at constant pressure, how can its volume (space occupied) be increased if it is free to expand?
   (*c*) Explain why the tires on your automobile are HARDER just after you have driven 10 miles at 60 mph than they were when you took the car out of the garage for the first time that day.
3. (*a*) What ignites the fuel in a gasoline internal combustion engine cylinder?
   (*b*) What effect has the fuel combustion on the piston?
   (*c*) What is the next step in the four-stroke cycle?
   (*d*) How many complete revolutions does the crankshaft make during a four-stroke cycle in a 16-cylinder engine?
4. (*a*) Explain why fuel is more economically used in the exhaust stroke of the four-stroke cycle than that of the two-stroke cycle.
   (*b*) Name another advantage of the four-stroke cycle for aircraft engines (other than economy of fuel use).
5. (*a*) What is the fundamental difference between in-line and radial aircraft engines?
   (*b*) Which type is most commonly used by the Navy?
   (*c*) What is the chief advantage of the type used by the Navy?

CHAPTER 2

MECHANICAL SYSTEM

1. (*a*) What name is given to the mechanism which controls the movement of the valves in an engine cylinder?
   (*b*) How does the structure of this mechanism affect the push rod?
   (*c*) What is the effect, on the valve, of the push rod's movement?
2. Name two functions performed by piston rings in an engine cylinder.
3. Why are reduction gears necessary in an aircraft engine?

CHAPTER 3

FUEL SYSTEMS

1. In a simple aircraft engine pressure system—
   (*a*) What is the function of the mechanical pump?
   (*b*) What supplies the power for the mechanical pump?
   (*c*) By what mechanism is the mechanical pump primed?
   (*d*) What is another function of this mechanism?
   (*e*) How is the carburetor protected against excessive pressure?
2. (*a*) To obtain the same amount of oxygen at higher altitudes as at lower altitudes, an aircraft engine must take in a greater volume of air. Why?
   (*b*) If the amount of fuel in the cylinders is not changed, what will be the effect on the mixture ratio of taking in a greater volume of air to obtain the same amount of oxygen? Why?
   (*c*) What part of the engine is designed to insure the engine's receiving the required volume of air at various altitudes?
3. (*a*) What is the purpose of the fan in the internal supercharges?
   (*b*) Trace the path of the mixture after it leaves the impeller (fan).

4. What is the difference between single-speed and two-speed superchargers?
5. (*a*) What is the fundamental difference between single-stage and two-stage superchargers?
   (*b*) What type of supercharger gets its power from exhaust gases?
   (*c*) What is the advantage of the two-stage supercharger?
6. What is the function of the carburetor in an internal combustion engine?
7. (*a*) Where is the needle valve located in a simple float type carburetor?
   (*b*) What is this valve's function?
8. (*a*) Through what parts of a simple float type carburetor does gasoline pass from the float chamber to the venturi tube?
   (*b*) What is the function of the venturi tube?

CHAPTER 4

IGNITION SYSTEM

1. Explain why current cannot be induced in a coil of wire by a magnet unless relative motion is set up between coil and magnet.
2. Under what circumstances will current NOT be induced in a coil of wire which is moving through a magnetic field?
3. Current is induced in a coil of wire by relative motion between a magnetic field (lines of magnetic force) and the coil. Explain how the necessary relative motion is set up in an aircraft engine magneto to induce current in—
   (*a*) The primary coil.
   (*b*) The secondary coil.
4. In an aircraft magneto—
   (*a*) How does an increase in the number of wire turns in the secondary coil increase the voltage in that coil?
   (*b*) How does the action of the circuit breaker increase secondary coil voltage?
5. In an aircraft engine magneto—
   (*a*) What device prevents arcing of current across the circuit breaker points?

(*b*) What device insures the direction of current to the spark plugs in their proper firing order?

(*c*) What device stops the aircraft engine by stopping the formation of high-voltage current needed by the spark plugs?

6. (*a*) What protection does the ignition harness give to aircraft radio?

   (*b*) In what three ways does the harness protect the ignition cable?

7. (*a*) What type of spark plug is most widely used on aircraft engines?

   (*b*) What is the other type?

   (*c*) To what characteristic of spark plugs do these type names refer?

   (*d*) What is another characteristic by which spark plugs are classified?

8. Trace the path of the spark-producing current from the distributor into the cylinder.

9. What will occur if shell electrode points are at different distances from the inner electrode point?

CHAPTER 5

LUBRICATION SYSTEM

1. (*a*) In a wet-sump engine, where is the oil carried?

   (*b*) Why is this type of lubrication system impractical for aircraft engines?

2. What is the chief difference between the functions of the external and internal lubricating systems?

3. How does oil get from the tank to the interior of the crankshaft in a radial aircraft engine?

4. In an aircraft engine—

   (*a*) Why is it dangerous to allow the pump to supply more oil than the engine needs?

   (*b*) What mechanism controls oil pressure?

   (*c*) How may this mechanism cause the pressure to fall too low?

5. Why is it easier to start a cold engine if the oil has been diluted?
6. In the oil dilution system developed for aircraft engines—
   (*a*) What device controls the system? Where and how is this device operated?
   (*b*) Explain briefly how the system accomplishes its purpose.
7. Name three measures that must be taken in connection with aircraft engine lubrication before starting the engine at air temperature below 10° F.
8. If the engine has been standing for several days, why should be turned over several times by hand before any attempt is made to start it?

CHAPTER 6

THE COOLING SYSTEM

1. Why do aircraft engines require cooling?
2. (*a*) What type of cooling system is used almost exclusively for Naval aircraft?
   (*b*) Name 5 advantages of this type of cooling system.
   (*c*) What structural advantage does the other type of cooling system offer?
3. In an air-cooled aircraft engine, where does the cooling air come from?
4. How is air cooling of cylinders facilitated by—
   (*a*) Fins?
   (*b*) Pressure baffles?
5. Why does an air-cooling system add less to the weight of an aircraft engine than does a liquid-cooling system?
6. Why should cowl flaps, if provided, be fully open during ground operations?
7. What are two coolants suitable for use in aircraft engines?
8. (*a*) What device measures cylinder operating temperature?
   (*b*) On what principle does the operation of this device depend?

CHAPTER 7

ENGINE ACCESSORIES

1. Name four types of engine starters used on aircraft of more than 300 horsepower.
2. By what mechanism are most of the units in the accessory section driven?
3. Why is a generator an essential part of the aircraft engine?
4. What simple device controls the action of aircraft gun synchronizers?

CHAPTER 8

OVERHAUL AND STORAGE

1. How often should most airplane engines be given a general overhaul?
2. Why must engines be especially prepared for storage?
3. What are four general steps you should take to "embalm" an engine in an airplane that is to be grounded for less than 30 days?
4. Where can you find specific instructions for "embalming" aircraft engines?
5. In "embalming" the engine of an airplane that is not to be used for 30 days or more—
   (*a*) What is the first step?
   (*b*) What should you do with respect to the crankcase?
   (*c*) What should you do with respect to the carburetor?
   (*d*) Where should dehydrating agents be anchored?
   (*e*) What is the final step?
6. How long before an engine is returned to operation should it be disembalmed?

CHAPTER 9

TROUBLE SHOOTING

1. If turning off the switch doesn't stop the engine, what three possible causes would you check?

2. If the oil temperature in an engine is too high, why should you check the piston rings if you can find nothing wrong with the lubrication system itself?
3. What is the first thing you should check if the engine does not run properly at idling speed?
4. What general engine difficulties may be caused directly by fouled or defective spark plugs?
5. Mention at least five possibilities you should investigate if the engine shows—
   (*a*) Improper fuel pressure.
   (*b*) Excessive fuel consumption.
   (*c*) Improper oil pressure.
   (*d*) Excessive oil consumption.
6. What is "cannibalizing"?
7. Which of the publications listed at the right would you consult for each type of information listed at the left?

(*a*) Starting procedure.	(1) Overhaul Manual.
(*b*) Up-to-date information on engine modification.	(2) Engine Bulletins and Changes.
(*c*) Detailed instructions for disassembly and repair of a valve mechanism.	(3) Pilot's Handbook.

CHAPTER 10

RANGER–V–770

1. On what airplane is the Ranger–V–770 engine used?
2. (*a*) How are this engine's cylinders arranged?
   (*b*) What is the chief advantage of this arrangement?
   (*c*) What is the chief disadvantage of this arrangement?
   (*d*) What is the means of overcoming this disadvantage?
3. What causes the knock heard when this engine is turned over very slowly?
4. In warming up the engine, how should you check the fuel flow?

CHAPTER 11

PRATT AND WHITNEY WASP JR.—R–985

1. On what airplane is the Pratt and Whitney Wasp Jr. engine used?
2. Describe this engine briefly with respect to—
   (*a*) Number and arrangement of cylinders.
   (*b*) Type of supercharger.
   (*c*) Weight.
   (*d*) Crankshaft.
   (*e*) Carburetor.
3. How soon and how often should this engine be inspected after installation in an airplane?
4. Fuel system and oil system are two of the major items on both pre-flight and after-flight check-off lists. What are the other major items on the—
   (*a*) Pre-flight check-off list?
   (*b*) After-flight check-off list?
5. Describe briefly the basic steps in starting this engine.

CHAPTER 12

WRIGHT CYCLONE R–1820

1. On what airplane is the Wright Cyclone R–1820 engine used?
2. Describe this engine briefly with respect to—
   (*a*) Number and arrangement of cylinders.
   (*b*) Supercharger.
   (*c*) Carburetor.
   (*d*) Oil tank.
3. What signs of leakage around the fuel line fittings of the engine should you look for?
4. Describe briefly the steps preparatory to starting this engine.
5. (*a*) What type of starter does this engine use?
   (*b*) How is this starter energized?
6. When should this engine be primed?

7. The Dauntless flies effectively at much higher altitudes than the Kingfisher. How might you have guessed this on the basis of what you know about their superchargers?
8. In chapter 4 you learned that when the primary wire is disconnected from the ignition switch, you cannot stop the engine. Why wouldn't you just turn off the fuel valve?

CHAPTER 13

PRATT AND WHITNEY TWIN WASP R–1830

1. (*a*) On what airplane is the Pratt and Whitney Twin Wasp R–1830–92 used?
   (*b*) What are the two modifications of this engine, and on what airplanes are they used? How many engines does each of these planes have?
   (*c*) What is the chief difference between the R–1830–92 and these two modifications?
   (*d*) What are the two chief differences between these two modifications?
   (*e*) How many cylinders has the Twin Wasp engine?
2. (*a*) The check-list for after-flight inspection of the Twin Wasp engine is similar to the list for what other engine?
   (*b*) On what airplane is the latter engine used?
3. What are the two means of starting the Twin Wasp engine?

CHAPTER 14

WRIGHT CYCLONE R–2600

1. On what airplanes is the Wright Cyclone R–2600 engine used?
2. (*a*) How many cylinders does this engine use?
   (*b*) Describe the cylinder arrangement, and the advantages of such arrangement.
3. (*a*) How should the fuel supply of this engine be checked in preflight inspection?
   (*b*) What further check on this should you make when starting the engine?

4. How should you check the operation of the supercharger in this engine?
5. (*a*) What is the maximum allowable cylinder head temperature for this engine?
   (*b*) What should the cylinder head temperature be when you are stopping the engine?

CHAPTER 15

PRATT AND WHITNEY DOUBLE WASP R–2800

1. (*a*) On what airplane is the Pratt and Whitney Double Wasp R–2800 used?
   (*b*) What are the important features in the performance of this type of airplane?
2. Explain the principal difference between the Twin Wasp and the Double Wasp engines.
3. What should you do if you find any water or dirt in the fuel sample you drain during preflight inspection of the engines?
4. In starting the engine—
   (*a*) Why is it dangerous to move or pump the throttle before the engine is running smoothly?
   (*b*) If the cartridge fires but the propeller doesn't turn over, what is the trouble and what is the remedy?
   (*c*) What does black smoke from the upper cylinder exhaust pipes indicate?
5. What are the general steps in stopping the engine?

ANSWERS TO QUIZ

CHAPTER 1

ENGINE PRINCIPLES

1. (*a*) 2,376,000 ft.-lbs. (900 lbs. × 2,640 ft.)

   (*b*) 9.6 horsepower (Jeep moving at rate of 4 mph will traverse one-half-mile hill in 7.5 minutes. 2,376,000 ft.-lbs. work performed in 7.5 min. = 316,800 ft.-lbs. per minute. 316,800 ft.-lbs. per minute ÷ 1 hp. = 316,800 ÷ 33,000 = 9.6).

2. (*a*) Pressure will decrease.

   (*b*) Increase its temperature.

   (*c*) The heat of friction occurring at 60 mph causes the air in the tires to expand and exert greater pressure.

3. (*a*) A spark produced across the points of the spark plug.

   (*b*) The pressure exerted by the hot, expanding gases forces the piston downward.

   (*c*) Exhaust stroke.—The burned gases are forced out of the cylinder through the exhaust valve as the movement of the connecting rod causes the piston to move upward again.

   (*d*) Two.

4. (*a*) The separate exhaust stroke of the 4-stroke cycle insures complete discharge of burned exhaust gases only, whereas the 2-stroke cycle not only fails to discharge all the burned exhaust gases but permits a part of the fresh fuel mixture to escape with the exhaust gases.

   (*b*) 4-stroke cycle is more flexible (able to accelerate quickly). Cylinders are easier to cool in 4-stroke cycle.

5. (*a*) In-line engines have their cylinders arranged on the crankcase in a straight line; whereas radial engines have them arranged radially (in circular rows) on the crankcase.

   (*b*) Radial.

   (*c*) Low weight per horsepower.

CHAPTER 2

MECHANICAL SYSTEM

1. (*a*) Cam.
   (*b*) Lobes on the cam plate periodically jog (bump) the push rod roller, momentarily tilting the push rod.
   (*c*) The upward tilt of the push rod causes the rocker arm to which it is attached to tilt downward, and thus causes the valve stem connected to the other end of the rocker arm to drop, opening the valve. The downward movement of the push rod after the jog releases the pressure on the rocker arm and valve stem, and allows a coiled spring to close the valve.
2. Prevent leakage of gas pressure from the combustion chamber. Minimize seepage of oil into the combustion chamber.
3. They cut down the crankshaft's speed of rotation as applied to the propeller, thereby keeping propeller blade vibration within safe limits.

CHAPTER 3

FUEL SYSTEMS

1. (*a*) To supply fuel from the tank to the carburetor under pressure.
   (*b*) Engine.
   (*c*) Wobble (hand) pump.
   (*d*) Supply fuel to the carburetor for starting. Function in event of failure of mechanical pump.
   (*e*) Excessive pressure automatically opens pressure relief valve in the line between mechanical pump and carburetor, and some fuel is returned to tank.
2. (*a*) Because at higher altitudes air weighs less, i. e., is less dense and contains less oxygen per cubic foot.
   (*b*) The mixture ratio will be unchanged. Because air at higher altitudes weighs less, the greater volume taken in in order to obtain the same amount of oxygen will not

increase the ratio of the weight of the air to the weight of the fuel.

(c) Supercharger.

3. (a) To impart velocity energy (which can then be converted into pressure energy) to the mixture.

   (b) It flies off the impeller blades into the diffuser, where it is compressed, and then into the distribution chamber from which individual intake pipes carry it to the cylinders.

4. The "speed" of the supercharger is the ratio between the speed of rotation of its impeller blades and of the crankshaft. In a single-speed supercharger this ratio is constant; a two-speed supercharger may be adjusted to either one of two ratios.

5. (a) The single-speed supercharger consists of one impeller installed in the diffuser section; whereas in the two-stage supercharger there is an additional impeller ahead of the carburetor.

   (b) Turbo supercharger.

   (c) It makes it possible to maintain engine efficiency at altitudes so high that the thin air requires more pressure than one impeller can build up.

6. To atomize gasoline and mix the fuel particles with oxygen in the correct proportions for effective combustion under all operating conditions.

7. (a) It is at the point in the carburetor where the gasoline enters the float chamber from the fuel line.

   (b) To control the passage of gasoline from the fuel line into the float chamber according to the amount of gasoline already in the chamber, by rising or dropping as the level of gasoline in the chamber causes the float to rise or drop.

8. (a) Metering jet and spray nozzle.

   (b) To lower, at its narrowest point, the pressure of the air sucked in through the air horn (by the downward movement of the piston in the cylinder) so that gasoline will be drawn out of the spray nozzle and vaporized.

CHAPTER 4

IGNITION SYSTEM

1. Induction occurs only when lines of magnetic force are cut by a conductor (for example, a coil or wire). When both coil and magnet stand still, no lines of force are cut.
2. When the coil is moving parallel to the field, therefore cutting no lines of magnetic force.
3. (*a*) Lines of force in the field expanding from and collapsing into the core as a result of its magnetization by the rotating magnet, are cut by the primary coil wound on the core. Current is induced in the primary coil.
   (*b*) Lines of force in the magnetic field expanding from and collapsing into the primary coil as a result of the flow of induced electrical current in that coil, are cut by the secondary coil wound around it. Current is induced in the secondary coil.
4. (*a*) By causing the coil to cut more lines of magnetic force per second.
   (*b*) By making and breaking the primary circuit rapidly so that the expansion and collapse of the magnetic field dependent upon the primary current will be more rapid, and more of its lines of magnetic force will be cut per second by the secondary coil.
5. (*a*) Condenser.
   (*b*) Distributor.
   (*c*) Ignition switch.
6. (*a*) It prevents radio interference caused by the electromagnetic field surrounding ignition cable.
   (*b*) It protects the cable against—
   Burning caused by the heat of the engine.
   Abrasion caused by vibration.
   Deterioration caused by oil and grease.
7. (*a*) Mica.
   (*b*) Ceramic.
   (*c*) Insulator material used.
   (*d*) Reach, or length of thread engagement into cylinder head.

8. The current is carried by cable from the distributor to the terminal at the end of the spark plug's inner electrode, flows down to the lower end or point of this electrode, and jumps the gap from this point to the lower end of a shell electrode. The lower part of the plug extends into the cylinder head.
9. Gap erosion, caused by the spark's consistently jumping the smallest gap instead of jumping alternate gaps with equal frequency.

CHAPTER 5

LUBRICATION SYSTEM

1. (*a*) In the crankcase.
   (*b*) The position of cylinders in the modern aircraft engine, in normal flight or in such maneuvers as inverted flight, exposes them to the danger of being flooded by oil carried in the crankcase.
2. The external system conveys oil between tank and engine. The internal system circulates oil to parts within the engine.
3. A pressure pump draws oil from the tank into an annulus (groove) around the interior of the rear bearing, from which pressure forces it through holes drilled in the crankshaft, into the hollow interior of the shaft.
4. (*a*) Oil might work up into the combustion chamber and foul the spark plugs, as well as produce an undue amount of carbon on the cylinder heads and pistons.
   (*b*) Relief valve (spring-loaded ball or plate).
   (*c*) If a piece of foreign matter gets into the valve, it will hold the valve open and so reduce pressure.
5. Diluted oil is less viscous and sticky, thus offers less resistance to turning (cranking).
6. (*a*) A spring poppet dilution control valve operated manually from the cockpit.
   (*b*) Holding the dilution control valve open for a short time before the engine is stopped allows a small amount of fuel to enter the oil inlet line and results in diluted

oil replacing heavy oil throughout the entire engine. Further, some of this diluted oil is returned to a hopper in the supply tank before the engine stops, so that diluted oil is the first pumped to the engine at the next start.

7. (*1*) Heat drained oil on stove; or heat oil in tanks by electric immersion heater.
   (*2*) Cover entire engine with canvas hood and heat with oil stove.
   (*3*) Before priming the engine, start warm oil flowing through interior by turning the engine over 15–20 revolutions with the switch off.
8. Oil may have leaked into the cylinders, and if the engine were started with the starter the cylinder heads might be blown off, or the pistons broken, or both.

CHAPTER 6

THE COOLING SYSTEM

1. To control the operating temperature, which might otherwise reach very dangerous degrees as a result of the extreme heat generated in engine cylinders.
2. (*a*) Air cooling.
   (*b*) Check your answer against page 78.
   (*c*) Liquid-cooled engines generally, having smaller frontal areas, lend themselves to better streamlining in the nose of the airplane.
3. Propeller stream.
4. (*a*) Fins increase the cylinder area exposed to the cooling air.
   (*b*) Baffles guide the air flow and increase its velocity over the cooling fins.
5. Liquid-cooling systems require coolant and auxiliary units (such as radiator, auxiliary expansion tank, and plumbing connections) not required by air-cooling systems.
6. Because cooling systems designed for efficiency at high air velocities are not efficient at low ones, so the added air obtained by opening the cowl flaps is necessary.

7. Water.
   Ethylene glycol (Prestone).
8. (*a*) Thermocouple.
   (*b*) Electromotive force is produced, and a measurable electric current generated, when one of two different metals joined together is kept at constant temperature while the exposed portion of the other metal is subjected to a change in temperature.

CHAPTER 7

ENGINE ACCESSORIES

1. Cartridge.
   Hand inertia.
   Electric inertia.
   Direct electric.
2. The main accessory drive shaft, through a gear arrangement.
3. Its power is needed to charge storage batteries which would otherwise be exhausted by the current requirements of electrical accessories while the airplane is in flight.
4. Rotating cam.

CHAPTER 8

OVERHAUL AND STORAGE

1. After about 350–400 hours of engine operation.
2. To protect them against corrosion while not in use.
3. (*1*) Remove spark plugs and rocker box covers.
   (*2*) Spray exhaust valves and cylinders with corrosion-preventive mixture.
   (*3*) Place dehydrating agent in exhaust outlets and in the carburetor intake scoop.
   (*4*) Put tags or plates in cockpit and on propeller, warning that engine has been embalmed.
4. Bureau of Aeronautics Technical Notes and Technical Orders.

5. (*a*) At the end of the final run, circulate a mixture of three parts lubricating oil and one part preservative compound through the engine.
   (*b*) Drain the lubricating oil from it while the engine is still warm.
   (*c*) Empty it of all gasoline and fill it with the specified oil.
   (*d*) In intake manifold and openings, in the carburetor intake if that device is to be left attached to the engine, and in other places as directed.
   (*e*) Place the engine in a moistureproof envelope.
6. Not more than a week before.

CHAPTER 9

TROUBLE SHOOTING

1. Magneto ground wires broken.
   Engine excessively hot.
   Excessive carbon.
2. Worn piston rings, or piston rings installed upside down, may result in too high oil temperature.
3. Idling jet—Check for restriction.
4. Failure of engine to start.
   Failure of engine to run properly at idling speed.
   Failure of engine to develop full power.
   Engine missing regularly on one or more cylinders.
   Excessive engine vibration.
5. Check your answers against pages 103-104.
6. An emergency means of getting parts needed for the repair of one airplane by removing them from another airplane.
7. (*a*) 3.
   (*b*) 2.
   (*c*) 1.

CHAPTER 10

RANGER–V–770

1. SO3C–1 (or –2) Curtiss Seagull.
2. (*a*) 60° V in-line arrangement.
   (*b*) Small frontal engine area.

(c) Only the front cylinders are exposed to cooling by direct air blast.

(d) Pressure cooling. (Air chamber next to cylinders.)

3. The crankshaft's dynamic vibration damper weights falling from one end of their track to the other as the particular crank throw moves across the top center.
4. Switch the selector valve to each tank in turn to be sure that normal pressure is maintained or returns to normal after a momentary drop.

CHAPTER 11

PRATT AND WHITNEY WASP JR.—R–985

1. OS2U–3 Kingfisher.
2. (a) Nine cylinders arranged radially.
   (b) Single-stage, single-speed centrifugal supercharger.
   (c) Approximately 675 pounds.
   (d) Single-throw, two-piece, split-pin crankshaft.
   (e) Stromberg updraft carburetor.
3. Fifteen–thirty hours after installation; and before and after each flight or at least at 50–75 hour intervals, depending upon operating conditions.
4. (a) Cowling; propeller; instruments.
   (b) Ignition; security of parts.
5. Insert cartridge in starter breech.
   Operate wobble pump.
   Prime engine.
   Turn on battery and generator switches.
   Turn ignition switch to BOTH.
   Turn starter switch ON for a moment.
   Remove cartridge from starter breech.
   Push in propeller control.

CHAPTER 12

WRIGHT CYCLONE R–1820

1. SBD–3 Douglas Dauntless.
2. (a) Nine cylinders arranged radially.
   (b) Single-stage, two-speed contrifugal supercharger.

(*c*) Holley down-draft carburetor with diaphragm mechanism replacing conventional float device.
(*d*) Oil is carried in an external tank, furnished with the airplane, not with the engine.

3. Blue stains made by aviation gasoline.
4. Check your answer against pages 147–148.
5. (*a*) Bendix inertia starter.
   (*b*) With a hand crank.
6. While the starter is being energized.
7. The Dauntless uses a two-speed supercharger, whereas the Kingfisher's is single-speed.
8. Air would be sucked into the fuel line.

CHAPTER 13

PRATT AND WHITNEY TWIN WASP R–1830

1. (*a*) PBY–5 Catalina.
   (*b*) R–1830–88 used on PB2Y–2 Consolidated Coronado (four engines). R–1830–86 used on F4F Grumman Wildcat (one engine).
   (*c*) The R–1830–92 has a single-stage, single-speed supercharger, whereas the R–1830–88 and –86 have two-stage, two-speed superchargers for high altitude performance.
   (*d*) Reduction gear and propeller drive: R–1830–86 has a reduction gear ratio of 3:2; R–1830–88 has a ratio of 16:9, and a decoupled propeller drive.
   (*e*) 14.
2. (*a*) R–1820–52 Wright Cyclone engine.
   (*b*) SBD–3 Douglas Dauntless.
3. Electric starter.
   Hand crank.

CHAPTER 14

WRIGHT CYCLONE R–2600

1. TBF–1 Avenger.
   SB2A–3.
   SB2C–1 Helldiver.
   TBM–1.

2. (*a*) Fourteen.
   (*b*) Cylinders are arranged in two banks, and staggered for cooling efficiency and for accessibility. Position of exhaust and intake ports on cylinders in front and rear banks is reversed, for concentration of exhaust heat away from the intake pipes.
3. (*a*) Fuel supply of all the tanks should be checked with a stick.
   (*b*) Check the supply in each tank, on the fuel gage.
4. Open the throttle to get a maximum of 30 inches of Hg; then shift the blower control to LOW without moving the throttle. A sudden drop in manifold pressure is a sign that the supercharger is working right.
5. (*a*) 205° C.
   (*b*) Below 149° C.

CHAPTER 15

PRATT AND WHITNEY DOUBLE WASP R–2800

1. (*a*) F4U–2 Corsair.
   (*b*) Maneuverability, rapid climb rate, speed, and concentrated fire power.
2. The Twin Wasp engine is single-stage supercharged; whereas the Double Wasp engine has a two-stage supercharger, the main stage having a fixed reduction gear ratio (single-speed) and the auxiliary stage being adjustable to two speeds.
3. Report it to a superior, and flush the strainer screen or clean it with an air hose.
4. (*a*) Discharge of excess fuel into the air ducts will create a fire hazard.
   (*b*) Load on the starter has blown open the safety disk or relief valve. Safety disk should be replaced, or, if it's a relief valve starter, another cartridge should be tried.
   (*c*) Over-priming.
5. Check your answer against page 192.